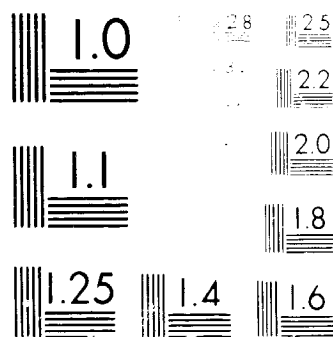


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OF A 1/4 SCALE POWERED HELICOPTER MODEL WITH
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AERODYNAMIC CHARACTERISTICS OF A 1/4-SCALE POWERED HELICOPTER MODEL WITH A V-TYPE EMPENNAGE

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Langley Research Center
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SUMMARY

An investigation was made in the Langley V/STOL tunnel to determine rotor induced effects on a 1/4-scale helicopter model with a conventional empennage and also a V-type empennage with dihedral angles of 45°, 50°, 55°, and 60°. Static longitudinal and lateral-directional stability data are presented for rotor advance ratios of 0.057, 0.102, and 0.192 in level flight and climb attitudes. The data are presented without analysis or discussion.

INTRODUCTION

Conventionally powered, single main rotor helicopters have experienced directional control problems while operating in low velocity, left rear quartering winds in ground effect, and during low-speed sideward flight in ground effect (refs. 1 and 2). Investigations have been conducted to determine the source of these directional control problems and possible means of alleviating them (refs. 3 to 5). Reference 4 showed that a V-type empennage presents significant advantages over conventional horizontal-vertical control surfaces with respect to helicopter directional control at low speeds. The principal advantages are: (1) smaller adverse fin forces and (2) increased tail rotor efficiency.

A subsequent unpowered investigation was conducted (ref. 6) to parametrically determine a V-type empennage configuration that approximated the directional and longitudinal characteristics of the conventional helicopter empennage. On the basis of that test, V-type empennages with 45°, 50°, 55°, and 60° dihedral have been tested in the Langley V/STOL tunnel to determine the rotor wake effect on the characteristics of the V-type empennage in forward flight.

SYMBOLS

Units used for the physical quantities defined in this paper are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. All measurements and calculations were made in U.S. Customary Units. Conversion factors are presented in reference 7.

Positive senses of forces, moments, and angles are presented in figure 1. Relative strain-gage balance positions and location of the model moment reference centers are shown in figure 2. Fuselage and tail longitudinal data are given in the stability axis system and lateral-directional data are presented in the body axis system. Rotor forces and moments are given in the control axis system.

a_0	rotor precone angle, deg
a_{1s}	first-harmonic rotor longitudinal flapping angle, deg
A_1	lateral cyclic control, deg

A	rotor disk area, πR^2
b	number of rotor blades
b_{1s}	first-harmonic rotor lateral flapping angle, deg
B_1	longitudinal cyclic control, deg
c	rotor blade chord, m (ft)
C_D	drag coefficient, $F_D/q_\infty A$
C_l	rolling-moment coefficient, $M_x/q_\infty \pi R^3$
C_L	lift coefficient, $F_L/q_\infty A$
C_{L_α}	lift-curve slope, deg^{-1}
C_m	pitching-moment coefficient, $M_y/q_\infty \pi R^3$
C_n	yawing-moment coefficient, $M_z/q_\infty \pi R^3$
C_H/σ	rotor horizontal force coefficient, $H_R/\rho_\infty A V_T^2 \sigma$
C_Q/σ	rotor torque coefficient, $Q_R/\rho_\infty A V_T^2 \sigma R$
C_T/σ	rotor thrust coefficient, $T_R/\rho_\infty A V_T^2 \sigma$
C_y	side-force coefficient, $F_y/\rho_\infty A$
C_{y_β}	directional stability parameter, deg^{-1}
D	rotor diameter, m (ft)
F_D	drag force, N (lbf)
F_L	lift force, N (lbf)
h/d	ratio of rotor height above test section floor to rotor diameter
h_h	distance of center of hub above shaft inclination point, cm (in.)
H_R	rotor horizontal force, N (lbf)
i_H	horizontal-tail incidence, deg
i_V	V-tail incidence, deg
M_x	rolling moment, N-m (lbf-ft)
M_y	pitching moment, N-m (lbf-ft)

M_z	yawing moment, N-m (lbf-ft)
q_∞	free-stream dynamic pressure, Pa (lbf/ft ²)
Q_R	rotor torque, N-m (lbf-ft)
R	rotor radius, m (ft)
S	V-tail planform area, m ² (ft ²)
T_R	rotor thrust, N (lbf)
V_T	rotor tip speed, ΩR , m/sec (ft/sec)
V_∞	free-stream velocity, m/sec (ft/sec)
X, Y, Z	model axis system
X_s, Z_s	distance from model reference system to rotor shaft inclination point, cm (in.)
α	angle of attack, deg
β	angle of sideslip, deg
γ	rotor shaft tilt angle, deg
Γ	dihedral angle, deg
θ_c	collective pitch angle measured at $0.75R$, deg
μ	rotor advance ratio, V_∞/V_T
ρ_∞	free-stream density, kg/m ³ (slugs/ft ³)
σ	rotor solidity, bcR/A
ϕ	roll angle, deg
ψ	blade azimuth position, deg
Ω	rotor rotational speed, rad/sec

Model component designations:

F	fuselage
R	rotor
S	conventional empennage

W wing

Vabc V-tail empennage where a, b, and c are as indicated in the following table:

a	Γ	b	s		c	i_v
			m ²	ft ²		
1	45	1	0.186	(2.000)	1	5
2	50	2	.244	(2.625)	2	8
3	55	3	.302	(3.250)	3	10
4	60					

Notation:

B.L. butt line

F.S. fuselage station

HP hub plane (shaft axis)

NFP no feathering plane (control axis)

TPP tip path plane

W.L. water line

MODEL AND APPARATUS

The model used in this investigation was the same model as described in reference 6 with the addition of a two-bladed rotor system. A photograph of the model in the Langley V/STOL tunnel is given in figure 3 and geometric characteristics are given in table I. The model consisted of the general rotor model system (GRMS) configured to approximate the attack helicopter of reference 1. Detailed descriptions of the model and drive system are given in references 6 and 8, respectively.

Schematics of the basic configuration and the empennages tested are given in figures 2 and 4. As shown in figure 2, the fuselage was wider than the exact 1/4 scale to accommodate the GRMS. The V-tail (fig. 4) had variable dihedral, incidence, and planform area features in order to investigate a variety of tail configurations.

The main rotor was a two-bladed teetering type with blades formed from fiberglass laid over nylon honeycomb cores. The geometric characteristics of the blades are given in table II and figure 5. One blade was instrumented with strain gages to measure blade loads during testing. Rotor collective and cyclics were remotely controlled. The model was mounted on the V/STOL tunnel high alpha-beta sting assembly. This model support system allows high angles

of attack and sideslip can be obtained and keeps the model near the center of the test section for pitch and yaw excursions.

TESTS AND CORRECTIONS

The tests were conducted in the Langley V/STOL tunnel, which is an atmospheric, closed-circuit wind tunnel. The test section, which measures 4.42 m by 6.63 m, can be configured three ways: (1) closed; (2) open (no walls or ceiling); and (3) slotted. The bulk of the tests were made at rotor advance ratios of 0.057 (open test section), 0.102 (closed), and 0.192 (closed). The normal rotor operating sweep was 1200 r.p.m. Angle-of-attack, angle-of-sideslip, rotor-collective, and longitudinal cyclic sweeps were made about measured trim conditions for the conventional horizontal tail set at 10° incidence.

Angle of attack and test section dynamic pressure were corrected for wall effects as suggested in reference 9. Drag data for the empennage were not corrected for tail cone chamber pressure.

The data were recorded on a digital data acquisition system. A data point consisted of an average of 50 samples of data acquired over a 5 second interval. All data presented in this paper were filtered above 2 Hz.

PRESENTATION OF DATA

Data obtained during this investigation are presented in a plotted form in figures 6 to 23. The rotor data are in the model control axis system with the hub being the moment reference center. Fuselage data are the forces on the total configuration with rotor and tail loads subtracted out. The tail data are the forces and moments on the tail surfaces and the tail cone from fuselage station 271.7 aft. Longitudinal data for the fuselage and tail are in the stability axis system. Lateral data are in the body axis system. The data are presented without analysis or discussion in the following order:

Figure

Longitudinal characteristics

Comparison of conventional tail and baseline

V-tail in l-g flight	6
V-tail in climb.	7

Effect of V-tail dihedral on the aerodynamic characteristics of the model	8
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Effect of V-tail planform area on the aerodynamic characteristics of the model	9
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Effect of V-tail incidence on the aerodynamic characteristics of the model	10
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Figure

Comparison of the baseline V-tail with right or left surfaces removed.	11
Comparison of the baseline V-tail with two nonsymmetrical dihedral configurations.	12
Effect of horizontal tail (conventional) incidence on the aerodynamic characteristics of the model	13
Lateral-directional characteristics	
Comparison of conventional tail and baseline V-tail 1-g flight	14
Climb.	15
Effect of V-tail dihedral on the aerodynamic characteristics of the model	16
Effect of V-tail planform on the aerodynamic characteristics of the model	17
Effect of V-tail incidence on the aerodynamic characteristics of the model	18
Comparison of the baseline V-tail with right or left surfaces removed.	19
Comparison of the baseline V-tail with two nonsymmetrical dihedral configurations.	20
Miscellaneous	
Comparison of rotor collective effects on the conventional tail and baseline V-tail	21
Comparison of rotor longitudinal cyclic effects on the conventional tail and baseline V-tail	22

Although it is not the intention of this paper to present an analysis of the data, an explanation of some of the data is necessary; in particular the fuselage and tail drag data. Due to a high ratio of downwash to free-stream velocities at low advance ratios, a large effective angle of attack is induced on the fuselage and tail. This induced angle of attack creates lift forces not necessarily perpendicular with the free stream, thereby creating negative drag (thrust) as can be seen in the data. Also, due to physical characteristics of the tail balance installation, the tail loads include the aft section of the tail cone. Since the data are presented as comparisons of one tail configuration with other tail configurations, all having the same tail cone, no corrections were made for the effect of chamber pressure on drag of the tail.

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TABLE I.- MODEL GEOMETRY

Wing:

Airfoil:

Root	NACA 0030
Tip	NACA 0024
Span, m (ft)	.0.786 (2.58)
Area, m ² (ft ²)	.0.159 (1.71)
Chord:	
Root, m (ft)	0.213 (0.700)
Tip, m (ft)	0.158 (0.520)
Incidence angle (chord line), deg.	14
Leading-edge sweep, deg.	14
Dihedral angle, deg.	0

Horizontal tail:

Airfoil.	Inverted Clark Y
Span, m (ft)	0.573 (1.88)
Area, m ² (ft ²)	0.0975 (1.05)
Chord:	
Root, m (ft)	0.183 (0.60)
Tip, m (ft).	0.137 (0.45)
Incidence angle (chord line), deg.	0, 6, 10
Leading-edge sweep, deg	20

Vertical tail:

Span, m (ft)	0.378 (1.24)
Area, m ² (ft ²)	0.0966 (1.04)
Chord:	
Root, m (ft)	0.341 (1.12)
Tip, m (ft).	0.171 (0.56)
Incidence angle (chord line), deg.	0
Leading-edge sweep, deg.	50

V-tails:^a

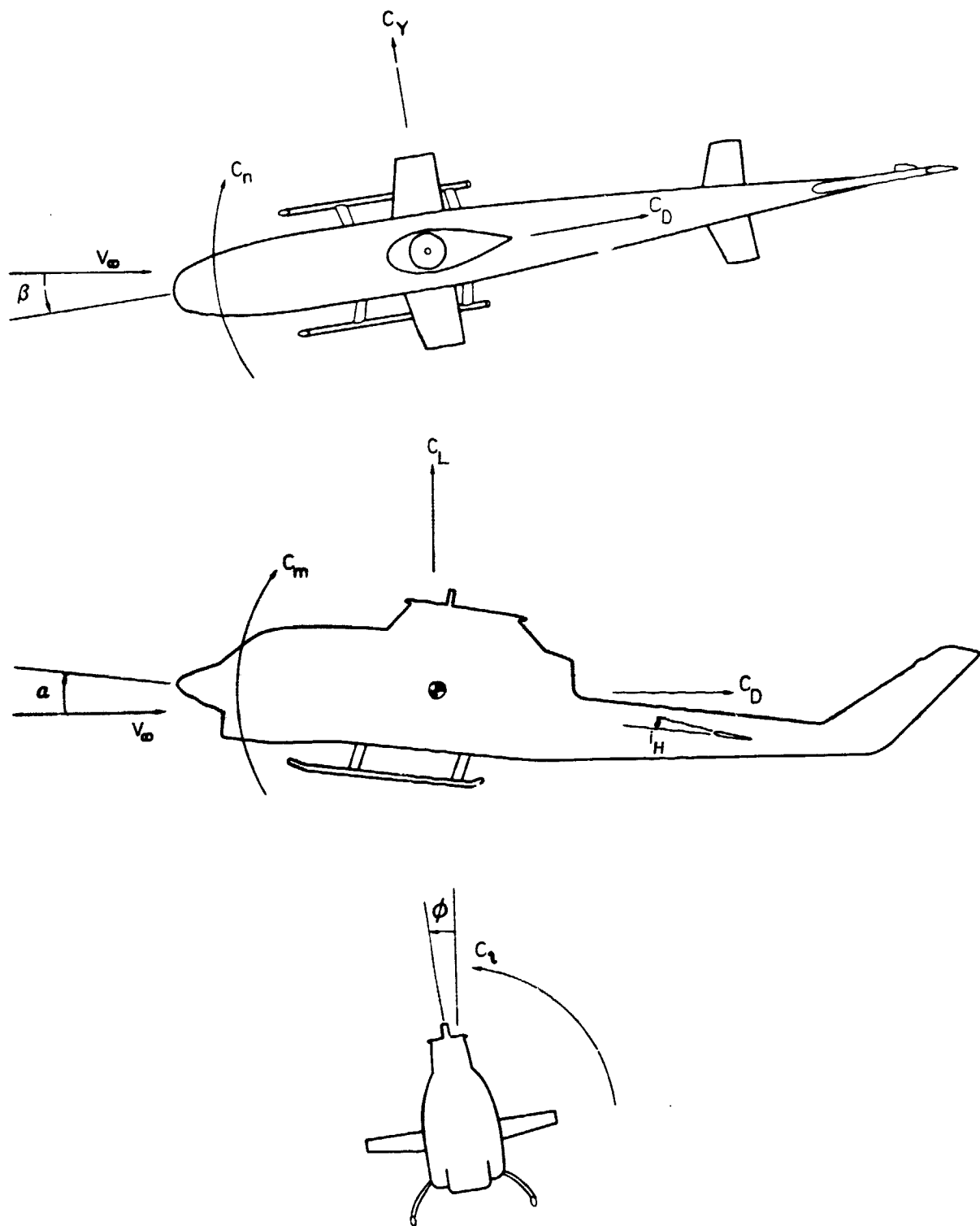
Airfoil.	NACA 4415
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^aSee figure 4 and Symbols for details.

TABLE II.- ROTOR GEOMETRY

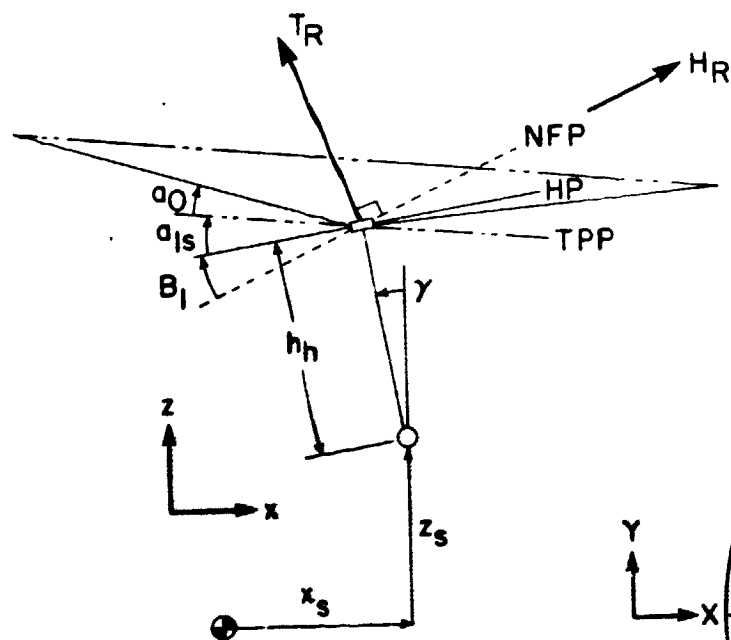
Radius, m (ft)	1.68 (5.50)
Disk area, m ² (ft ²)	8.83 (95.0)
Chord, cm (in.)	17.14 (6.75)
Twist, deg.	10°
Precone, deg.	2.5°
Solidity	.0065
Airfoil section	(a)
Cutout, percent R	.16.7%
h_h , cm (in.)	0.00 (0.00)
x_s , cm (in.)	0.00 (0.00)
z_s , cm (in.)	51.80 (20.39)
γ , deg.	0
a_o , deg	2.5

(a) Coordinates are given in reference 3.

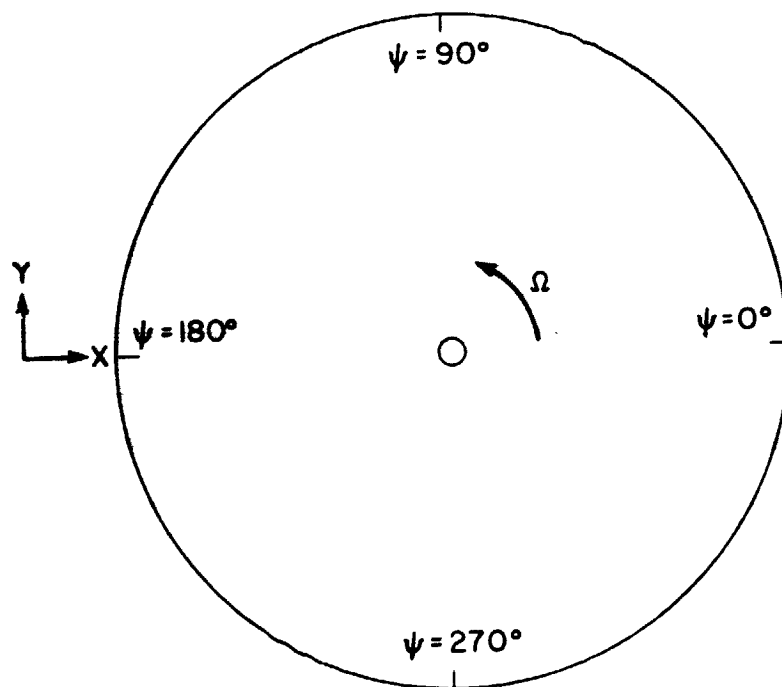


(a) Fuselage

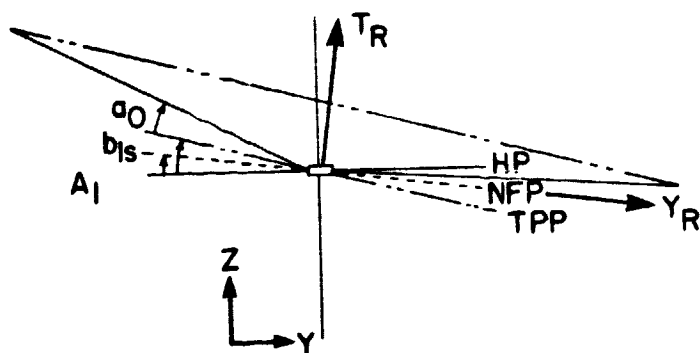
Figure 1. - Axes and sign conventions. Positive directions are indicated by arrows.



View from left



View from top



View from rear

(b) Rotor system
Figure 1.- Concluded.

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1/4 Scale attack helicopter (ref. 1)

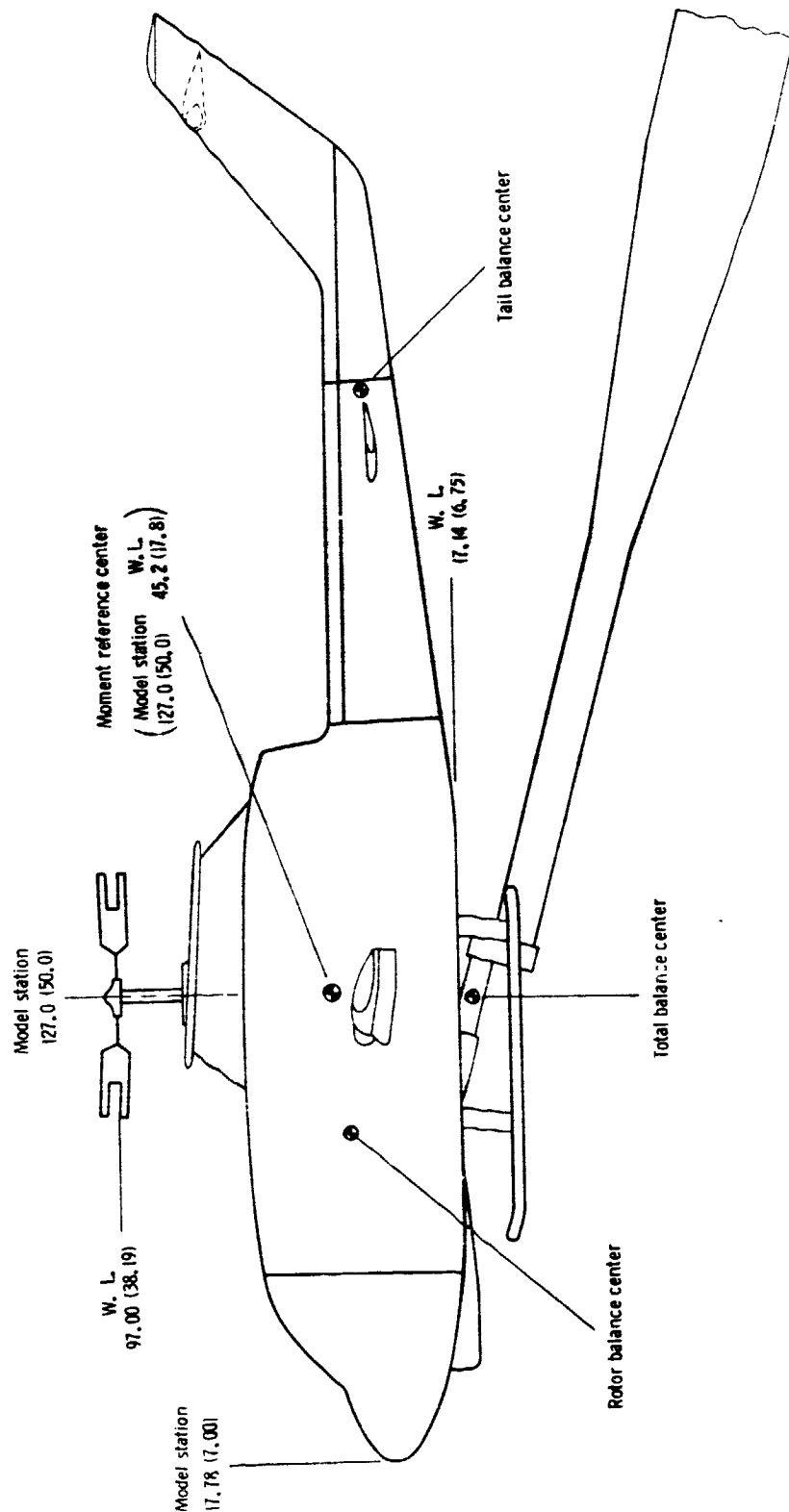
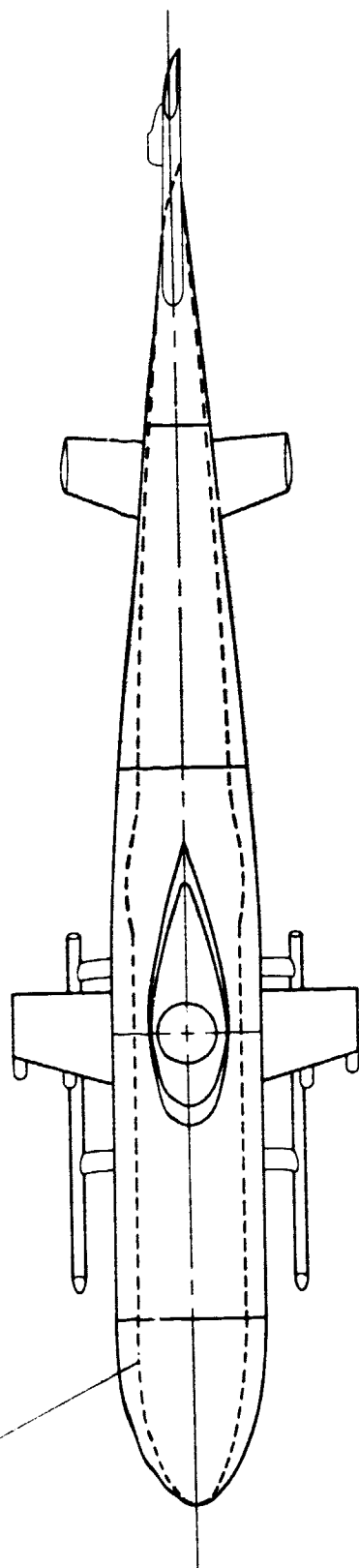


Figure 2 - Model geometry. Dimensions in inches.

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Figure 3. - Model in test section.

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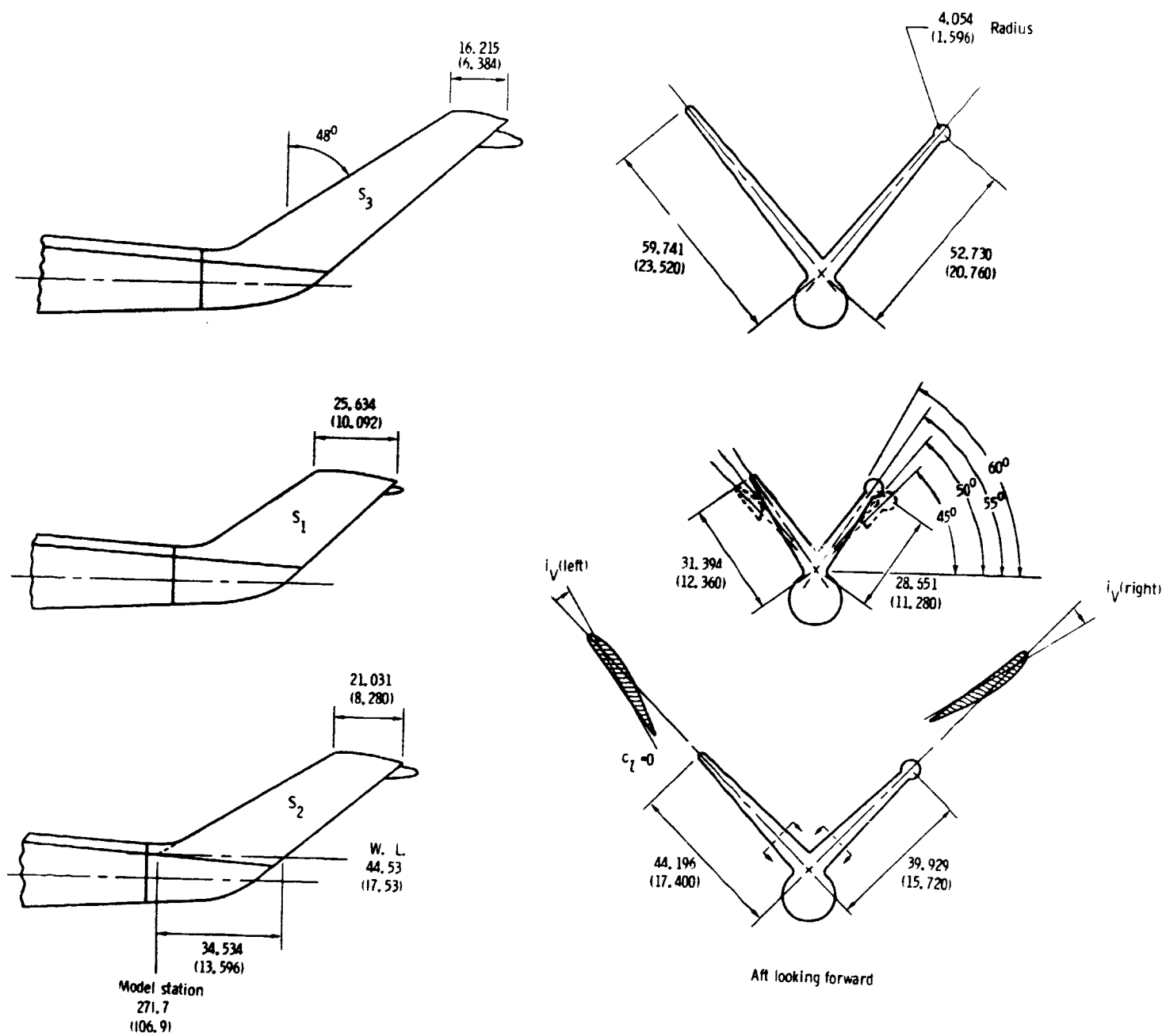


Figure 4. - V-tail geometry.

Dimensions: cm(in.)

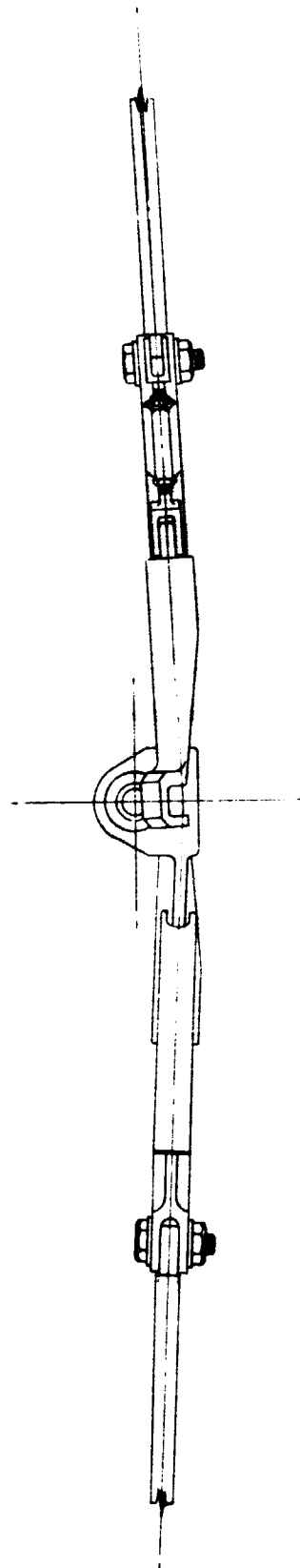
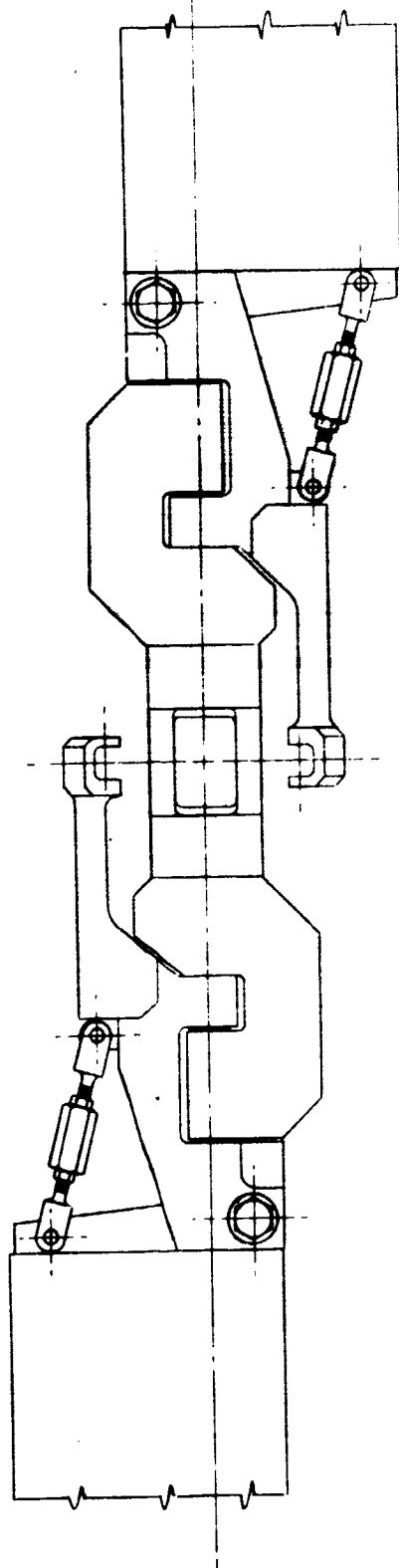
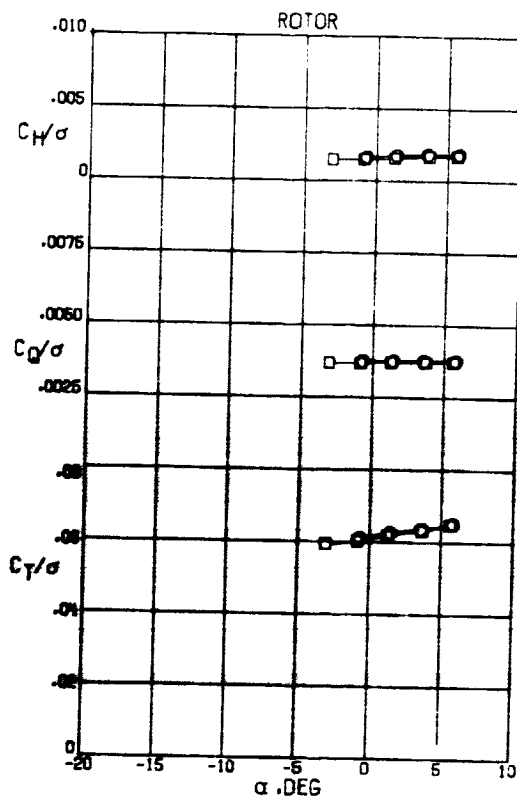
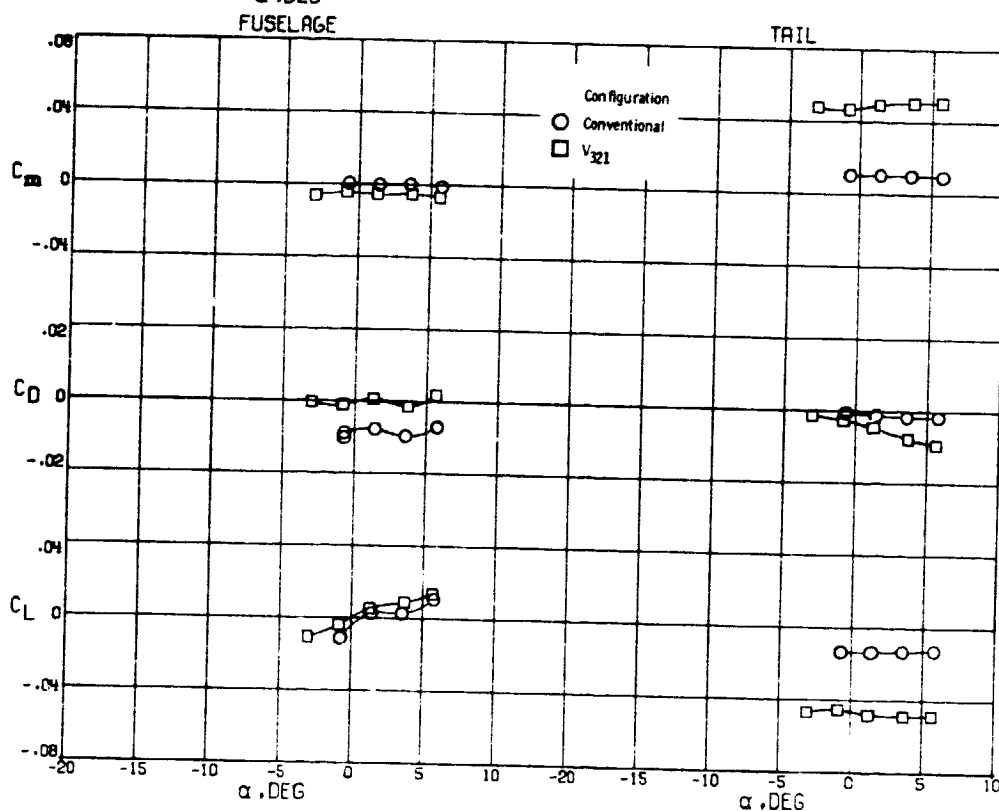


Figure 5.- Sketch of hub assembly.

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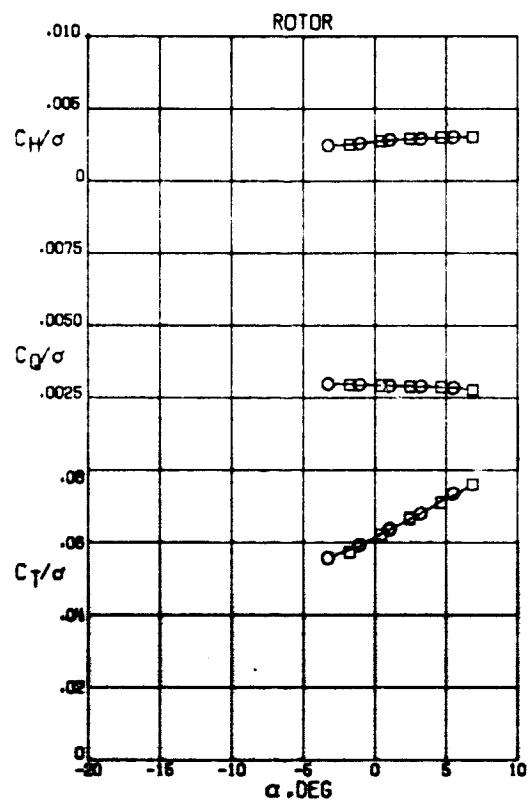


α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○ R	.0	.057	4.6	-.9	3.7	-2.6	1.3
□ R	.0	.056	4.6	-.9	3.7	-2.3	1.1

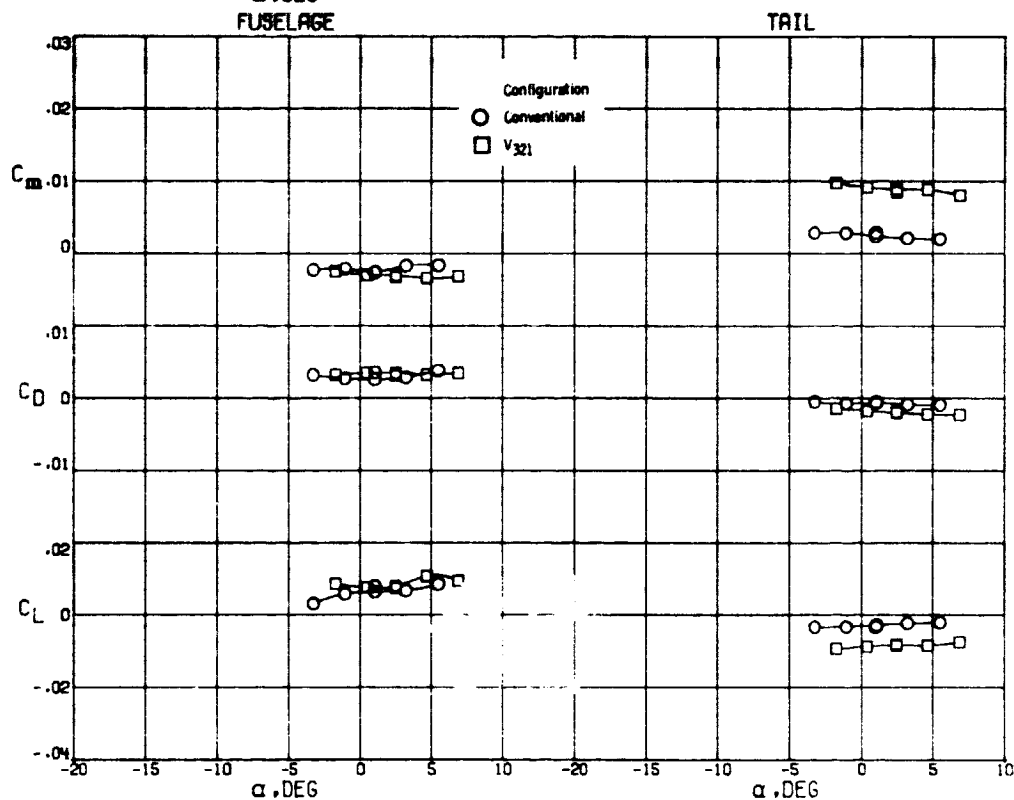


(a) $\mu = 0.057$

Figure 6.- Longitudinal aerodynamic characteristics of the conventional tail and the baseline V-tail in 1-g flight at three advance ratios.



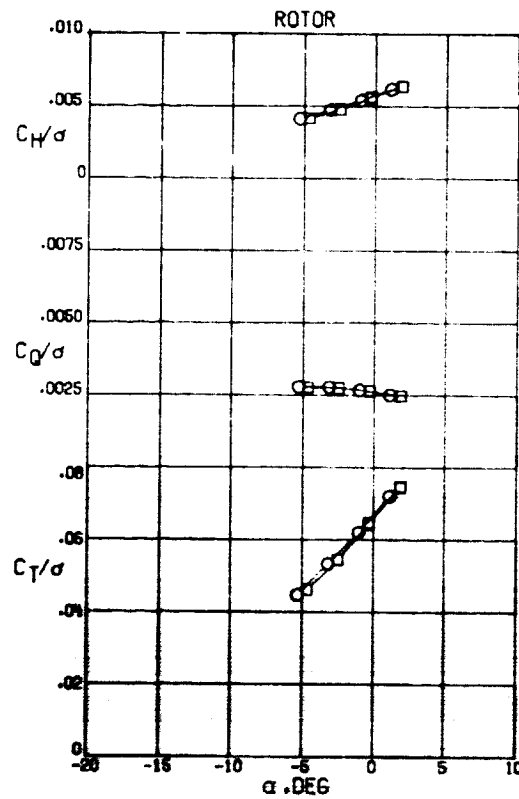
	α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.100	3.3	-.9	4.0	-2.0	.7
□	R	.0	.102	3.4	-1.0	4.0	-1.5	.7



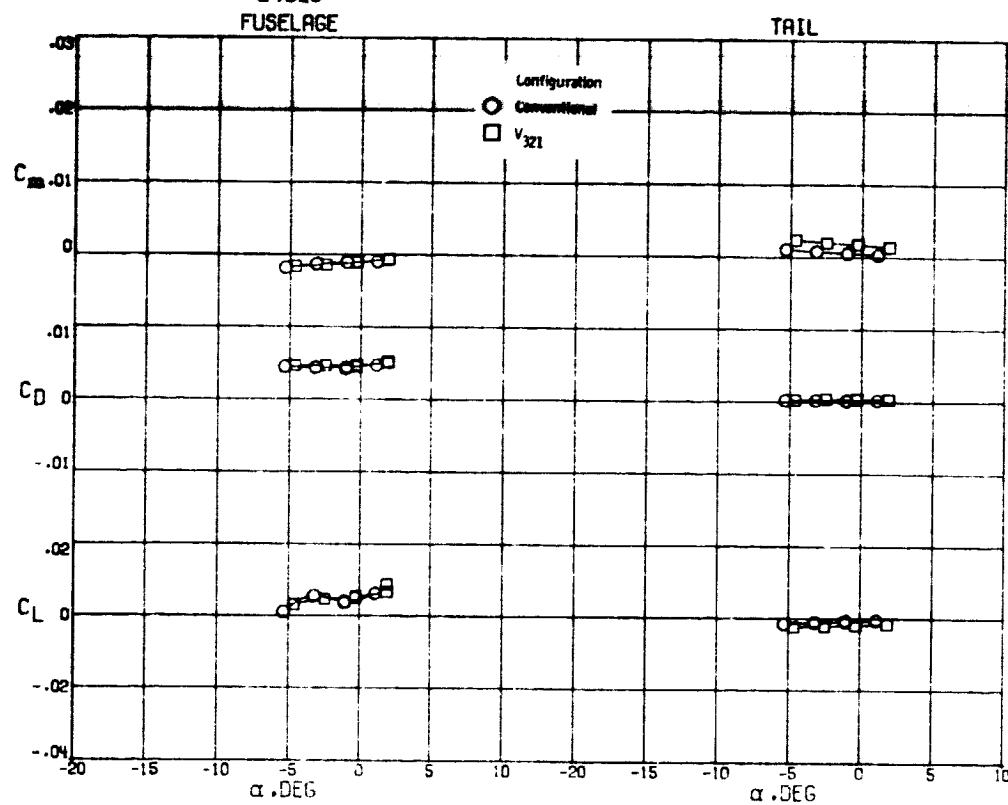
(b) $\mu = 0.102$

Figure 6- Continued.

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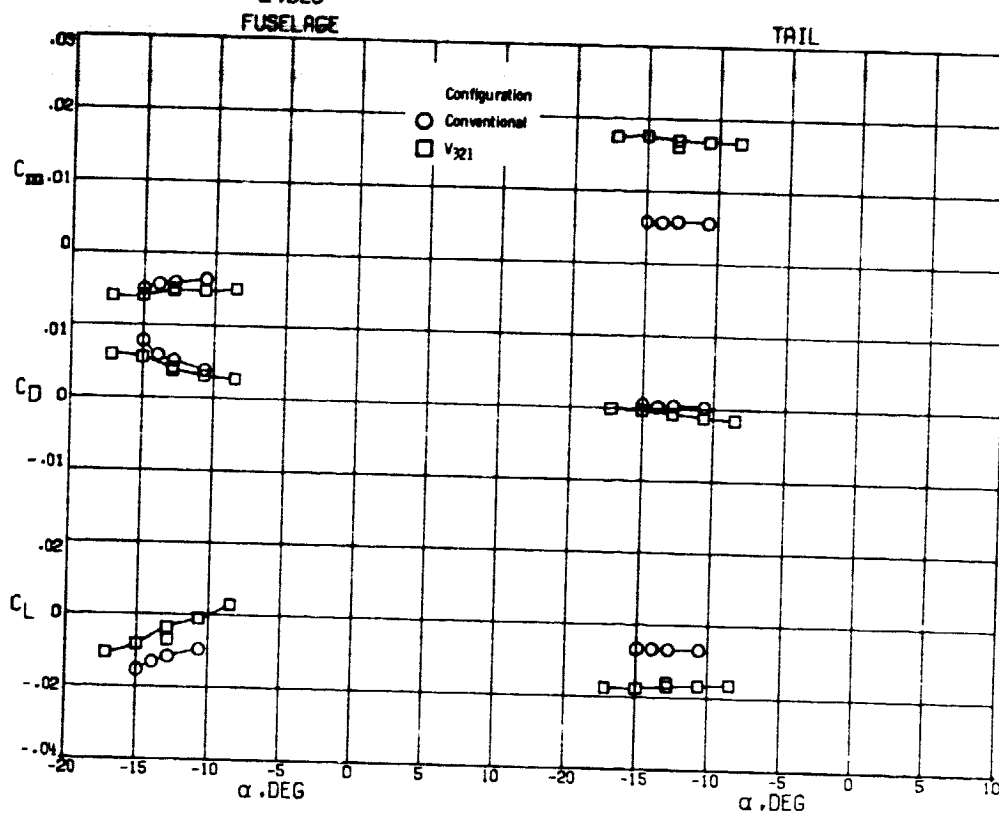
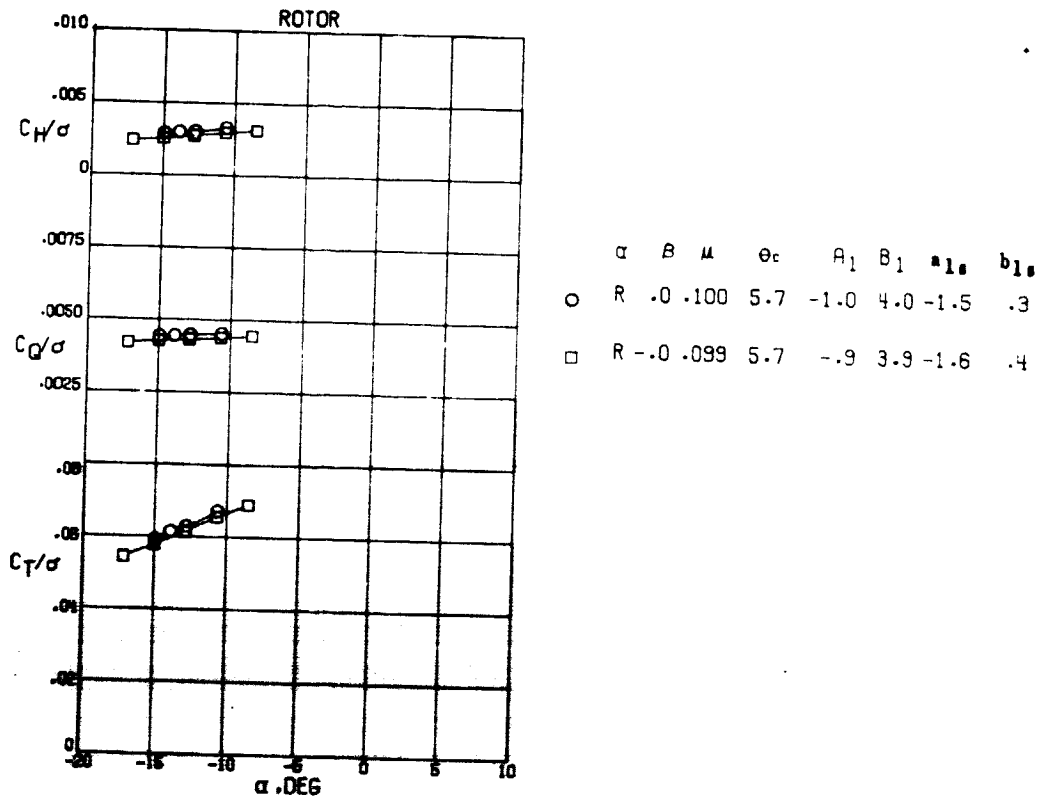


	α	B	M	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.190	3.2	-1.0	4.6	-1.4	.3
□	R	.0	.193	3.2	-1.0	4.6	-.9	.2



(c) $\mu = 0.192$

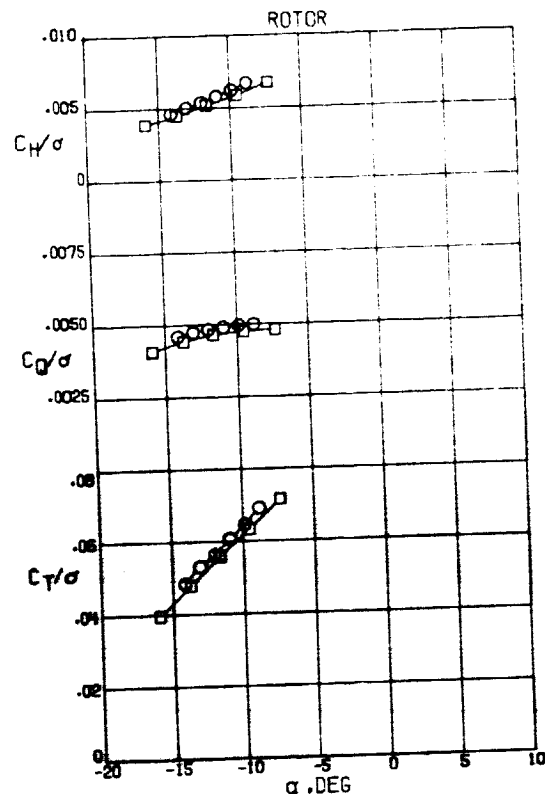
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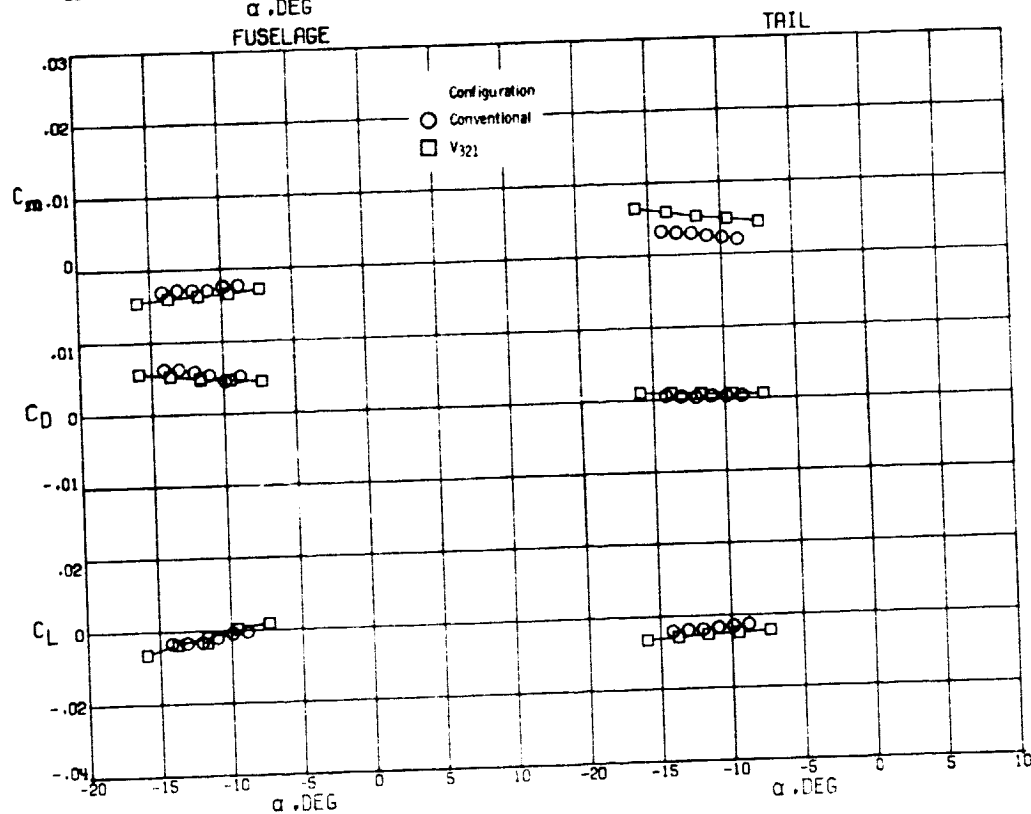
(a) $\mu = 0.102$

Figure 7. - Longitudinal aerodynamic characteristics of the conventional tail and the baseline V-tail in climb at two advance ratios.

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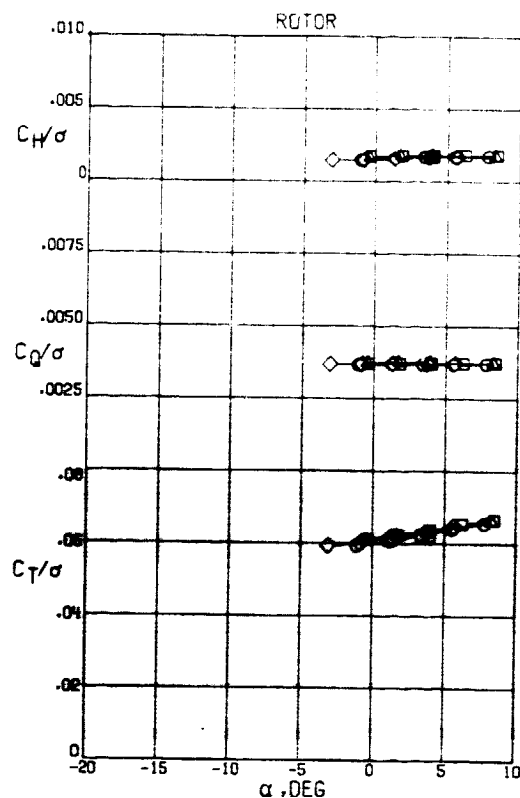


	α	β	M	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	-.1	.189	6.7	-.9	5.4	-1.2	.2
□	R	.0	.186	6.7	-1.0	5.4	-1.3	.3

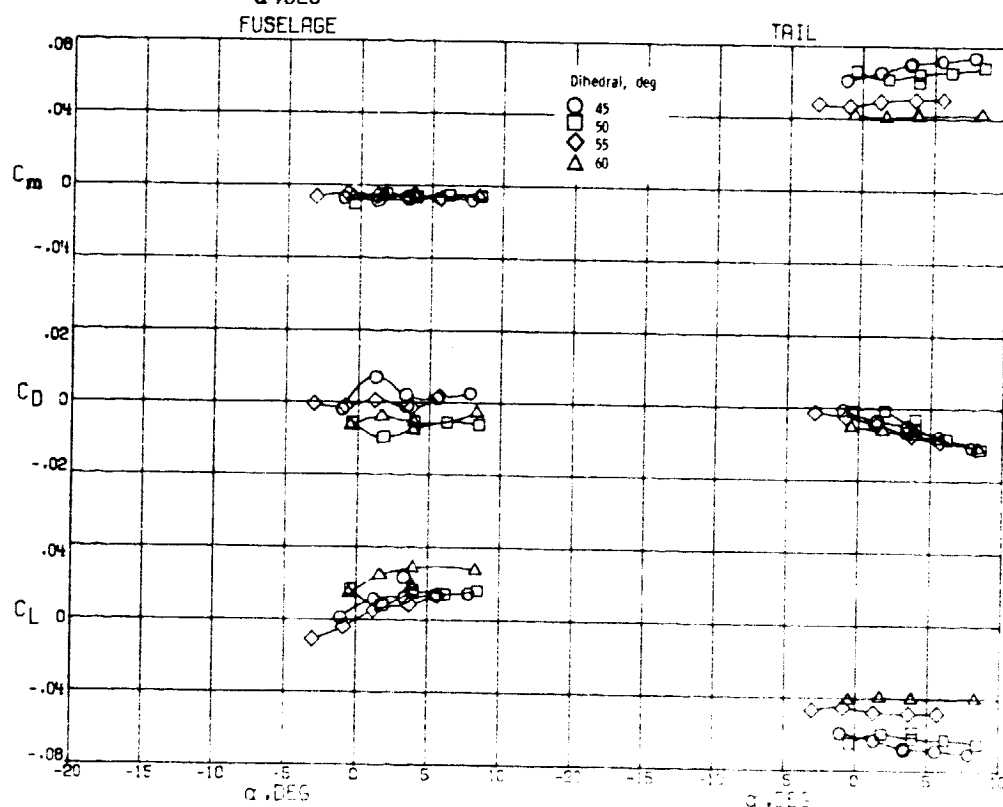


(b) $\mu = 0.192$

Figure 7. - Concluded.



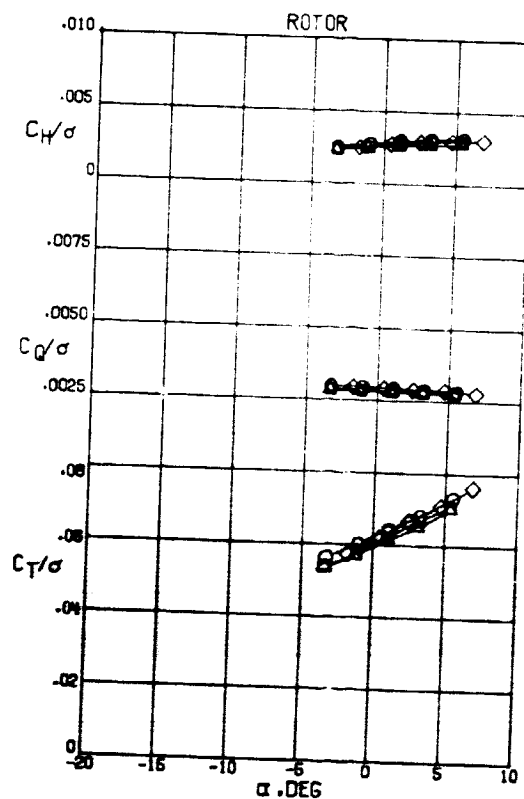
	α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	-0	.055	4.7	-.9	3.7	-2.1	1.1
□	R	.0	.055	4.7	-.9	3.8	-2.3	1.3
◇	R	-0	.056	4.6	-.9	3.7	-2.3	1.1
△	R	.0	.055	4.7	-1.0	3.8	-2.3	1.3



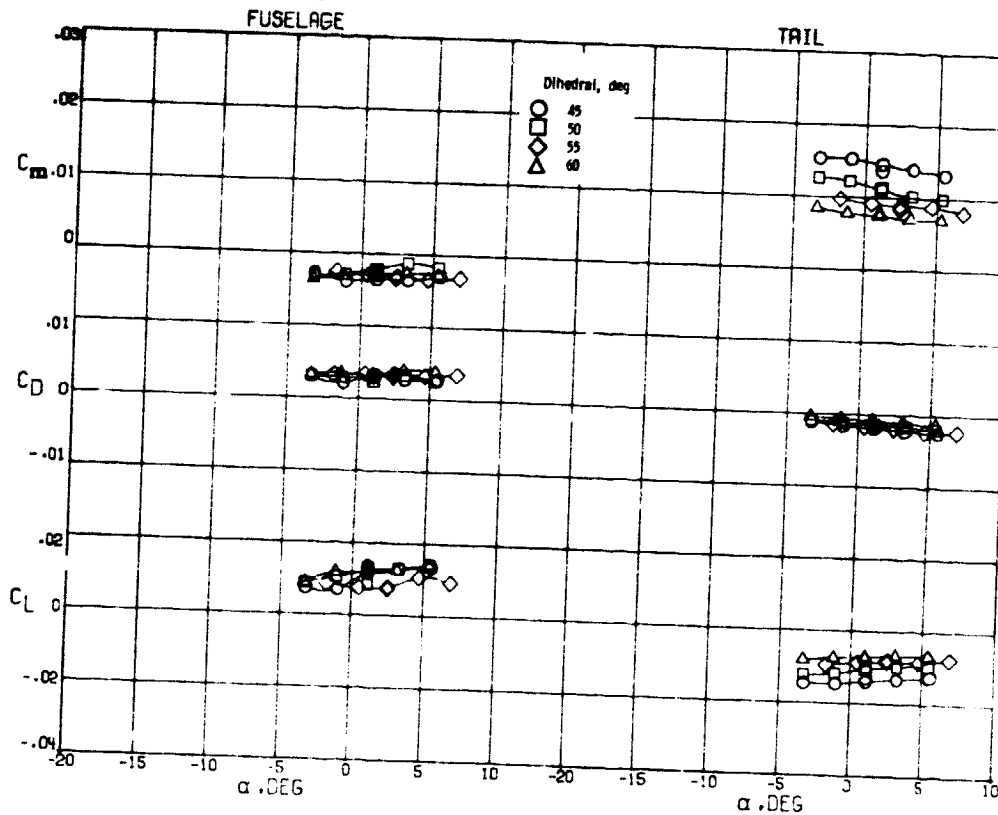
$\mu = 0.057$

Figure 8.- Effect of V-tail dihedral on the longitudinal aerodynamic characteristics of the model at three advance ratios.

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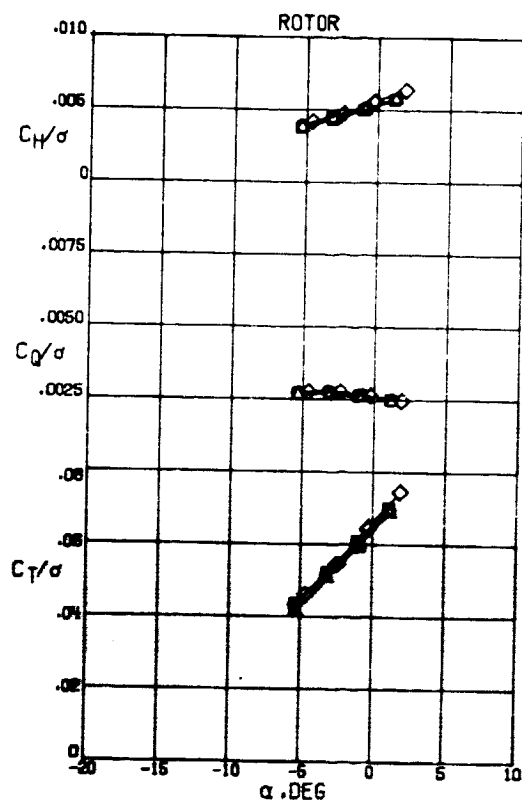


	α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.098	3.3	-.9	4.0	-2.2	1.0
□	R	.0	.099	3.3	-1.0	4.0	-2.1	1.0
◇	R	.0	.102	3.4	-1.0	4.0	-1.5	.7
△	R	.0	.099	3.3	-.9	4.0	-2.2	1.0

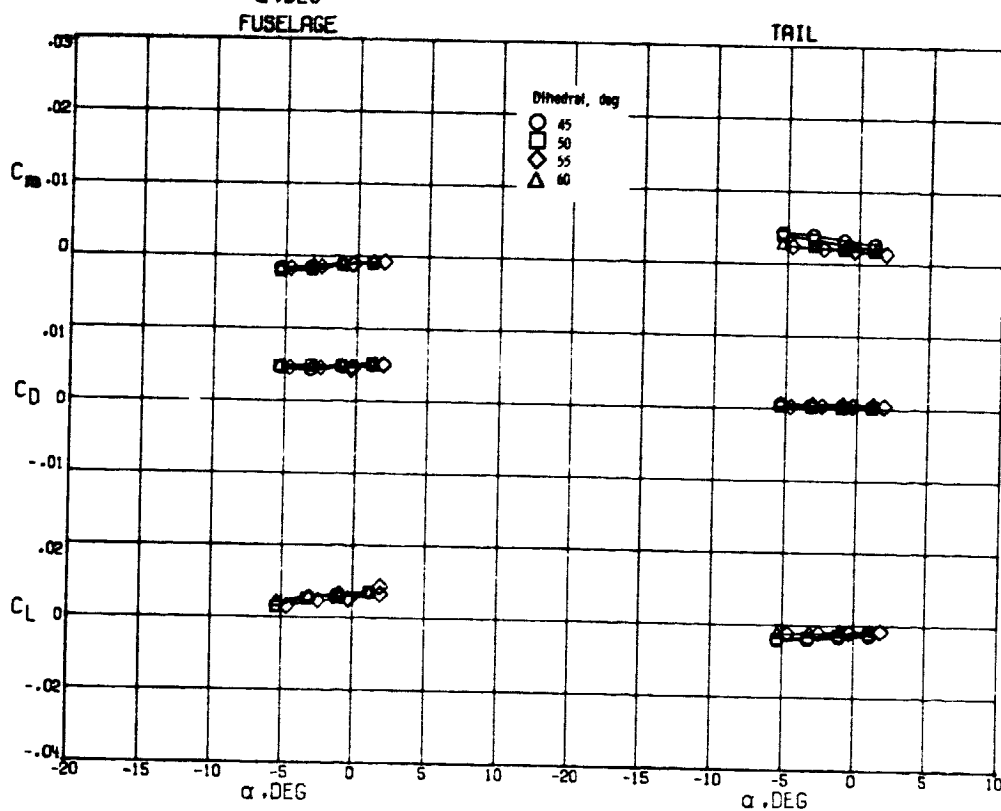


(b) $\mu = 0.102$

Figure 5. - Continued.



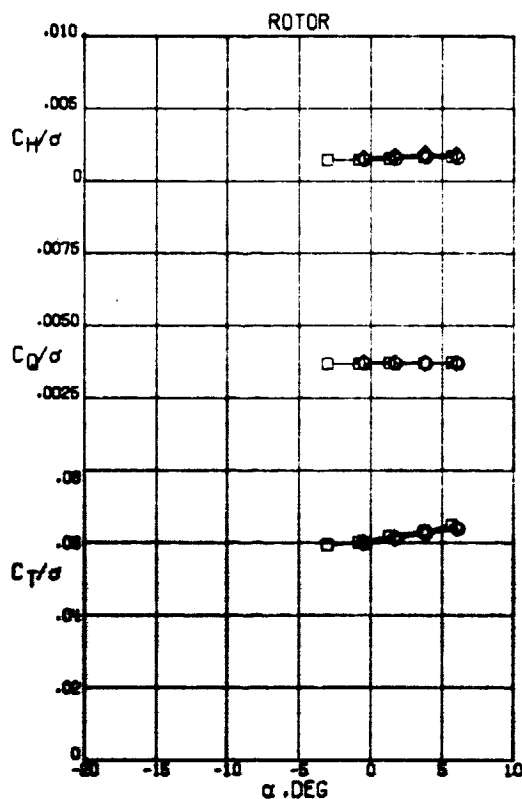
	α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.187	3.2	-1.0	4.6	-1.6	.4
□	R	.0	.187	3.2	-.9	4.6	-1.5	.4
◇	R	.0	.193	3.2	-1.0	4.6	-.9	.2
△	R	.0	.188	3.2	-.9	4.6	-1.6	.4



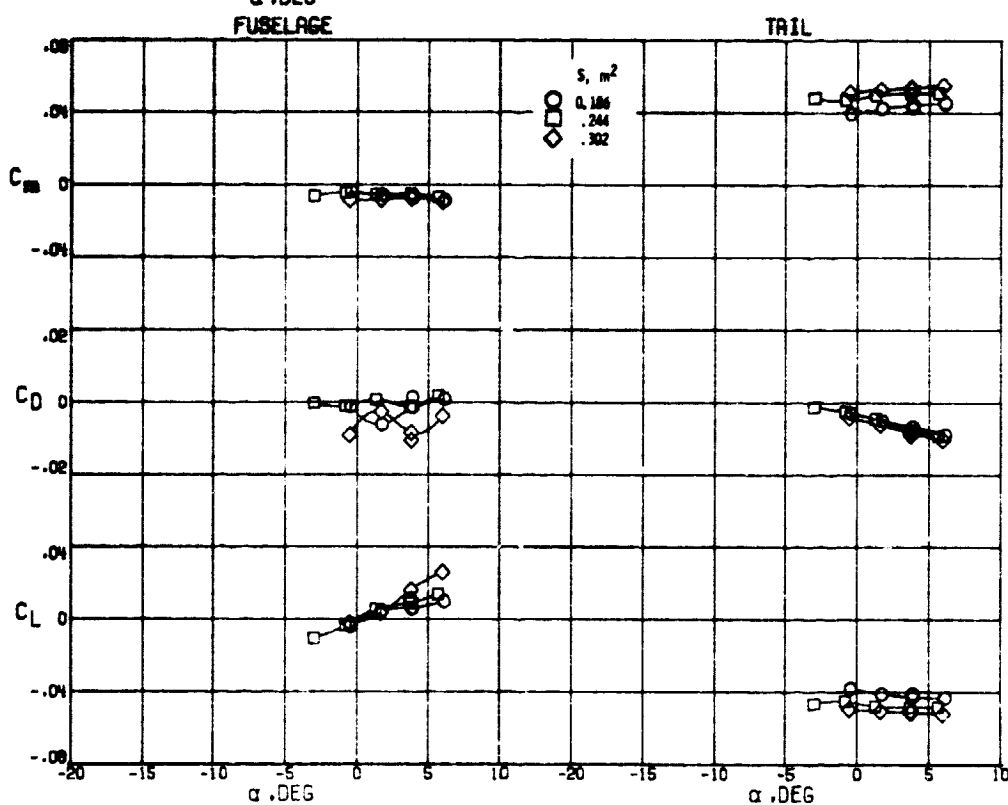
$\mu = 0.102$

Figure 8.- Concluded.

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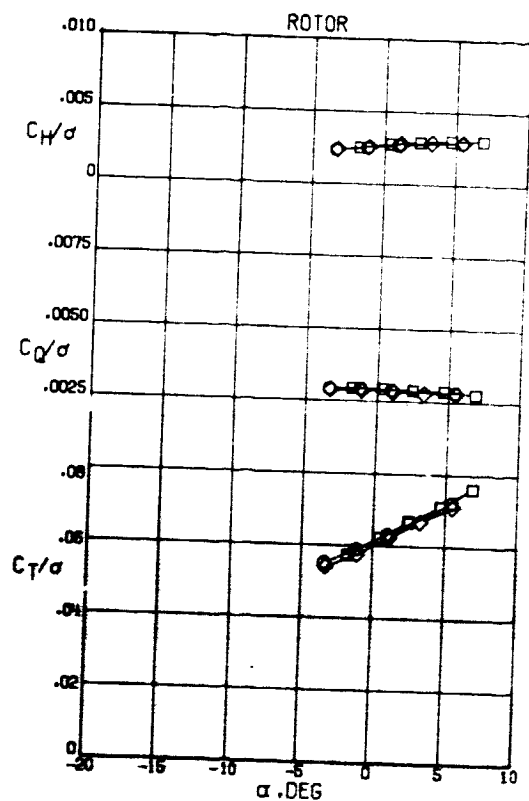


	α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.056	4.7	-.9	3.8	-2.5	1.3
□	R	.0	.056	4.6	-.9	3.7	-2.3	1.1
◇	R	.0	.056	4.6	-.9	3.7	-2.4	1.3

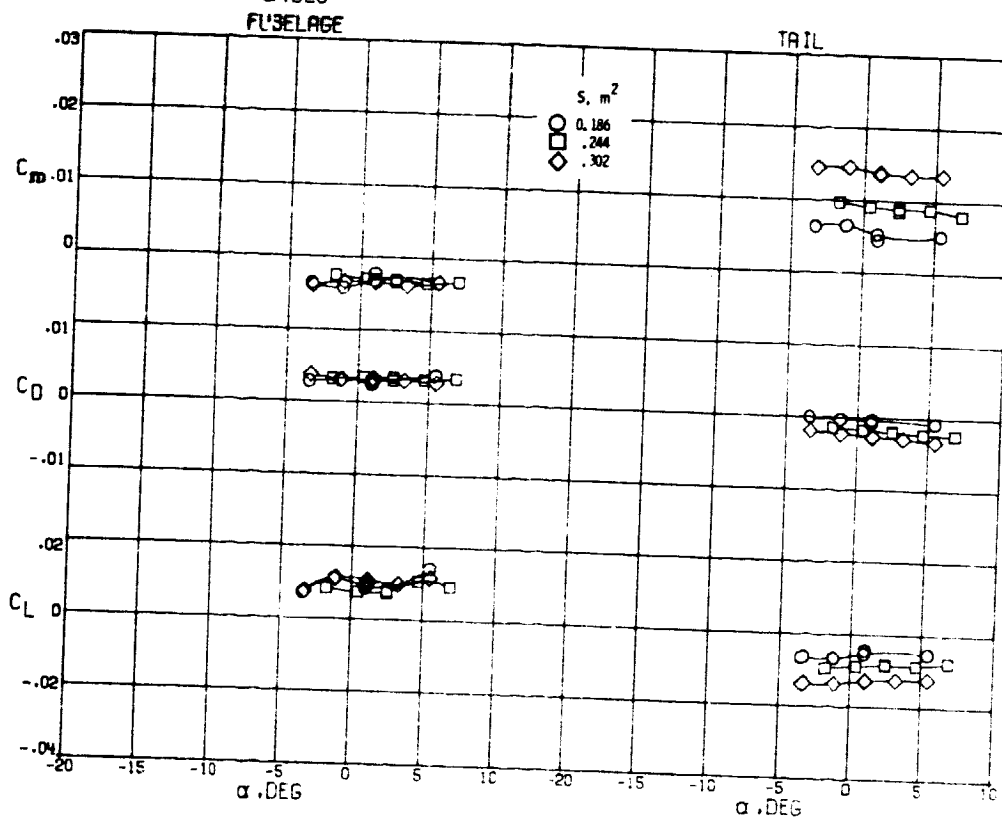


(a) $\mu = 0.057$

Figure 9. - Effect of V-tail planform area on the longitudinal aerodynamic characteristics of the model at three advance ratios.



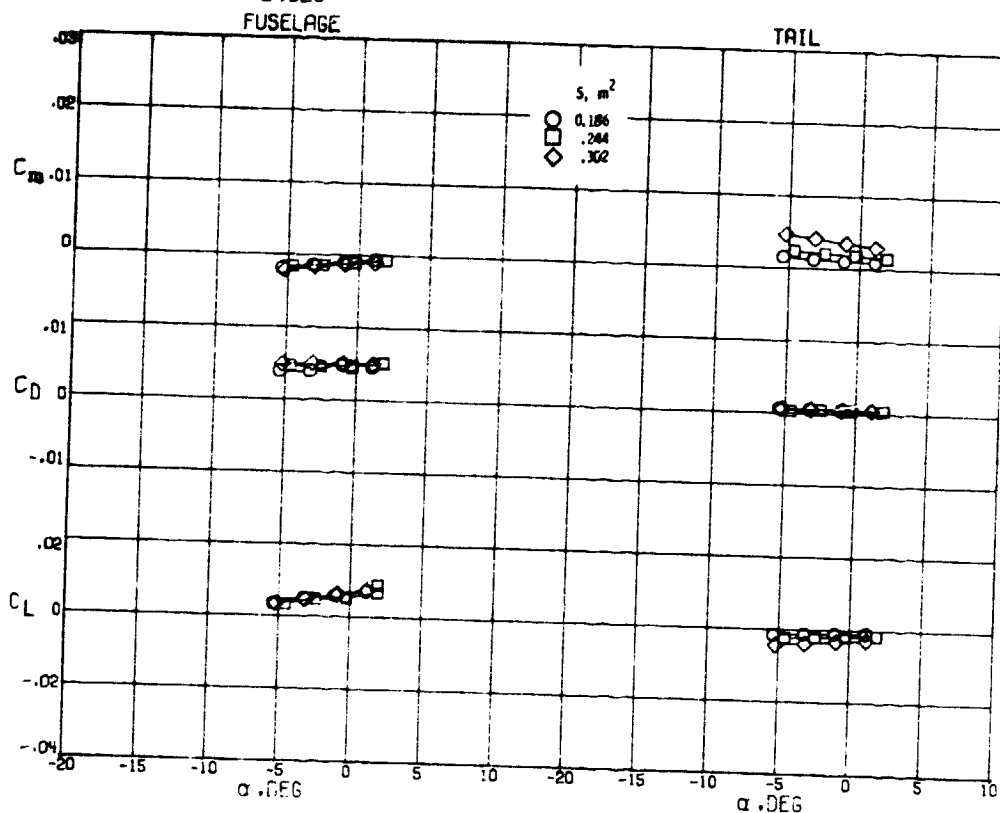
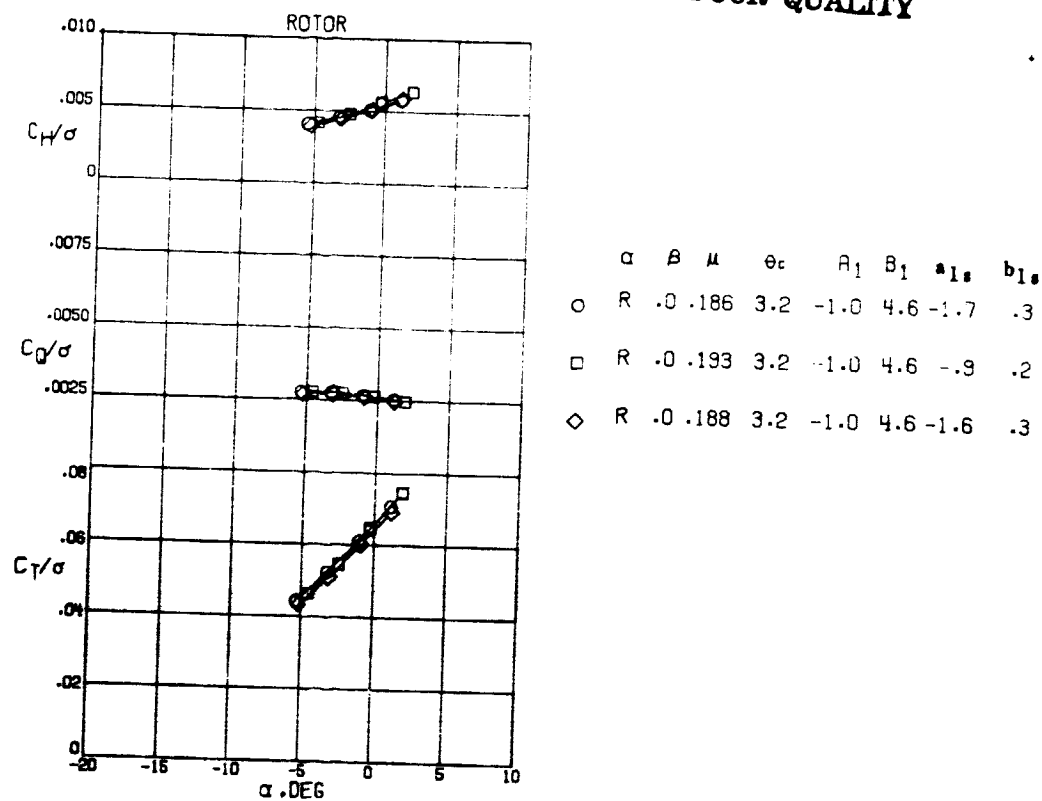
	α	B	μ	θ	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.098	3.3	-1.0	3.9	-2.2	.9
□	R	.0	.102	3.4	-1.0	4.0	-1.5	.7
◇	R	.0	.099	3.3	-1.0	4.0	-2.2	.9



$\mu = 0.102$

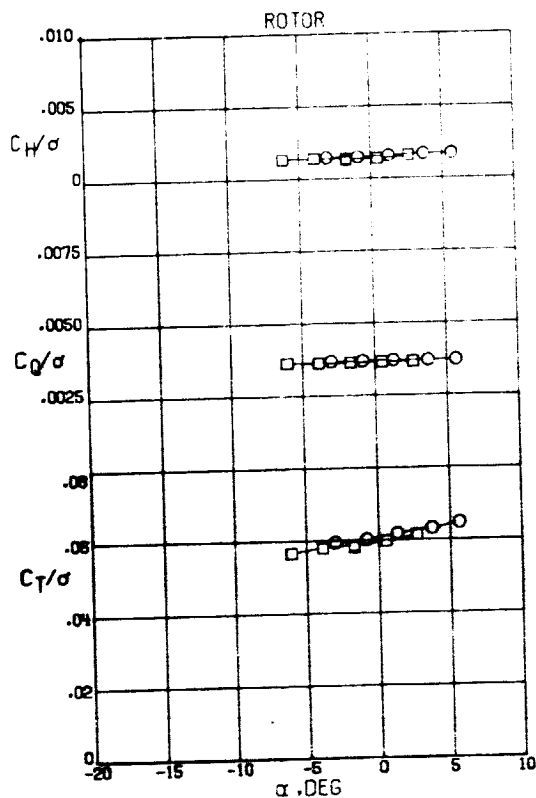
Figure 9. - Continued.

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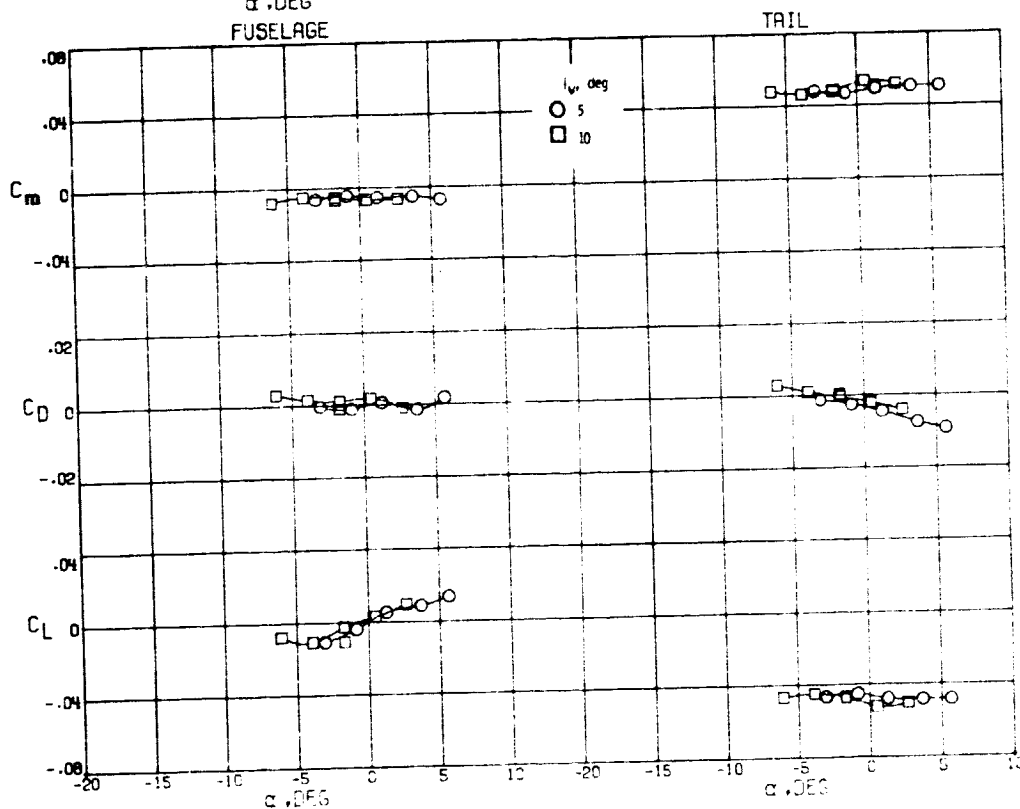


$Re \cdot \mu = 0.192$

Figure 9. - Concluded.



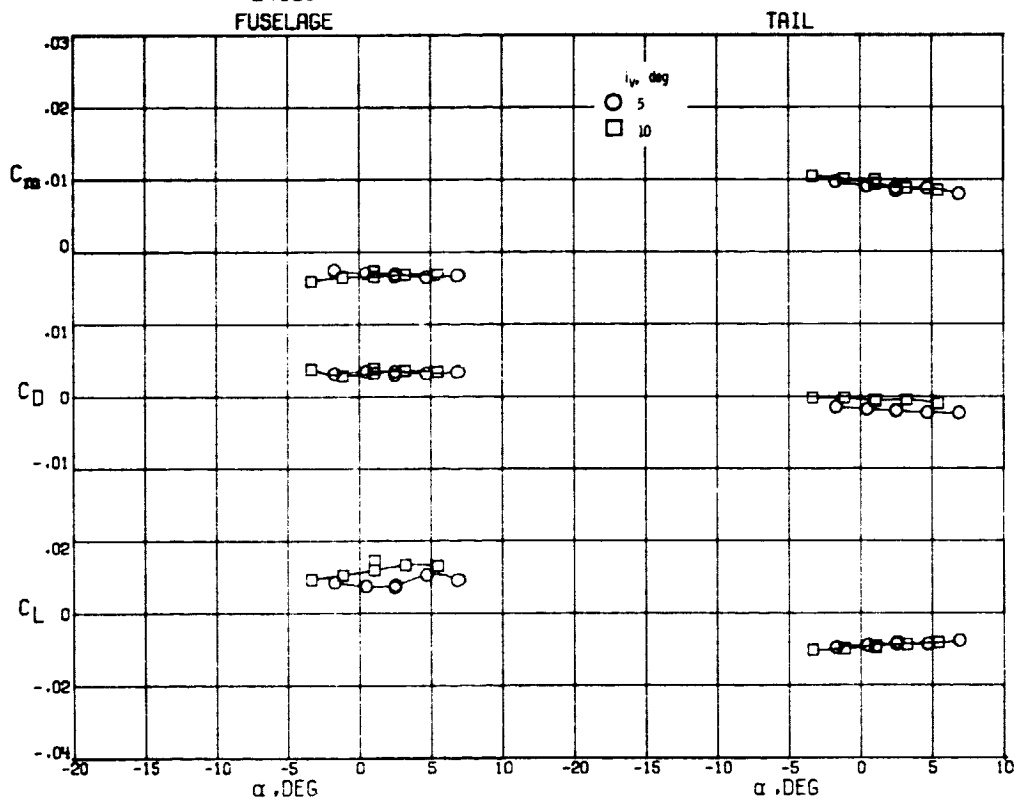
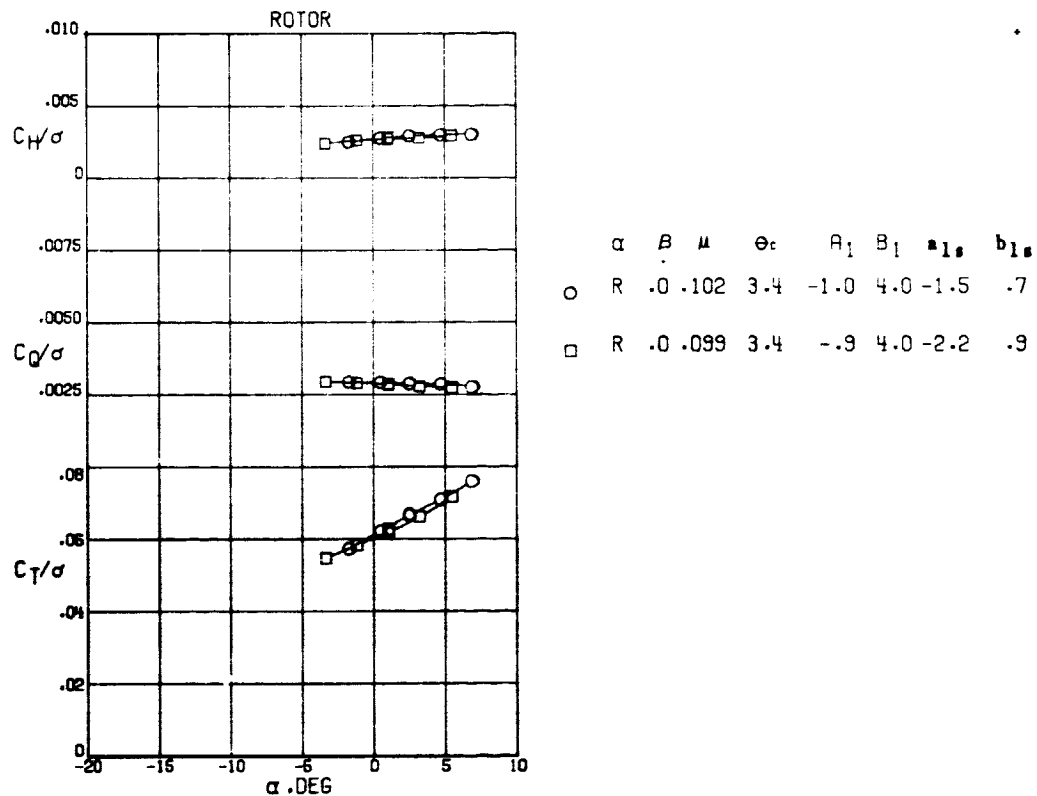
	α	β	μ	θ	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.056	4.6	-.9	3.7	-2.3	1.1
□	R	.0	.053	4.6	-.9	3.7	-1.8	.8



$\mu = 0.167$

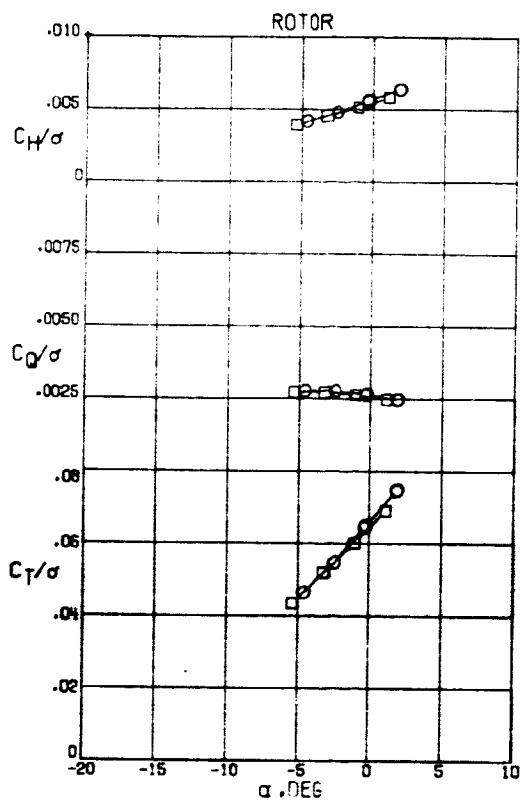
Figure 10.- Effect of V-tail incidence on the longitudinal aerodynamic characteristics of the model at three advance ratios.

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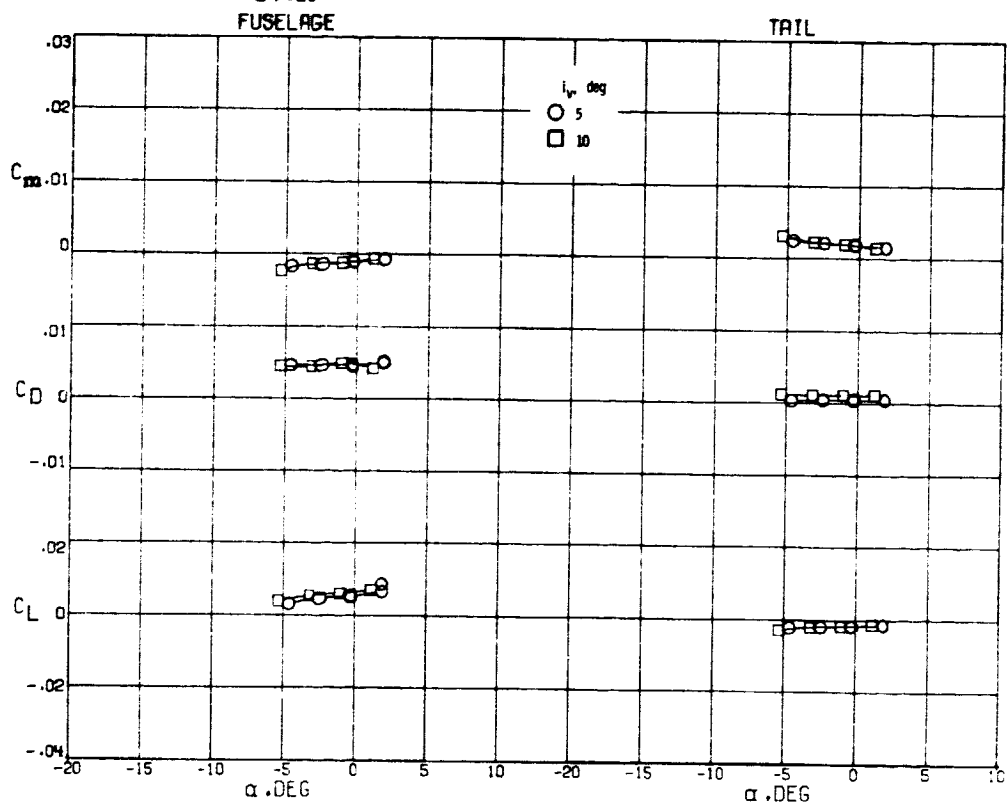


(b) $\mu = 0.102$

Figure 10.- Continued.

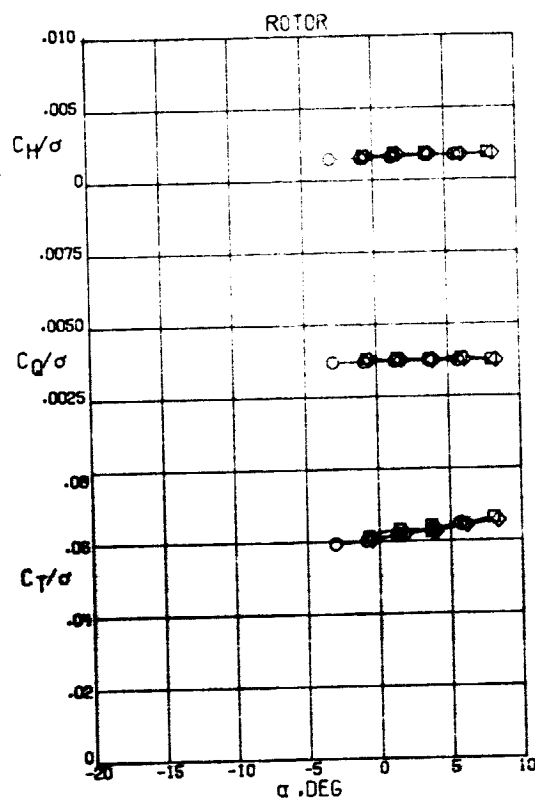


α	B	M	θ_c	A_1	B_1	a_1	b_1
○ R	.0	.193	3.2	-1.0	4.6	-.9	.2
□ R	.0	.187	3.2	-1.0	4.6	-1.6	.3



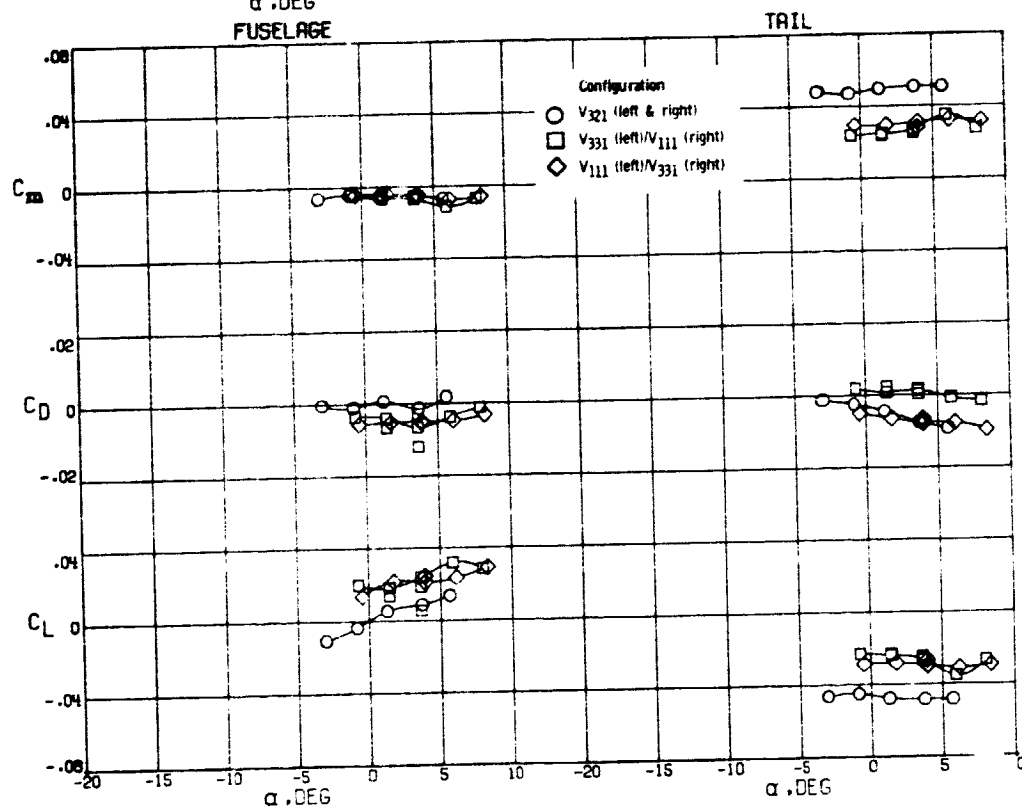
(c) $\mu = 0.192$

Figure 10.- Concluded.



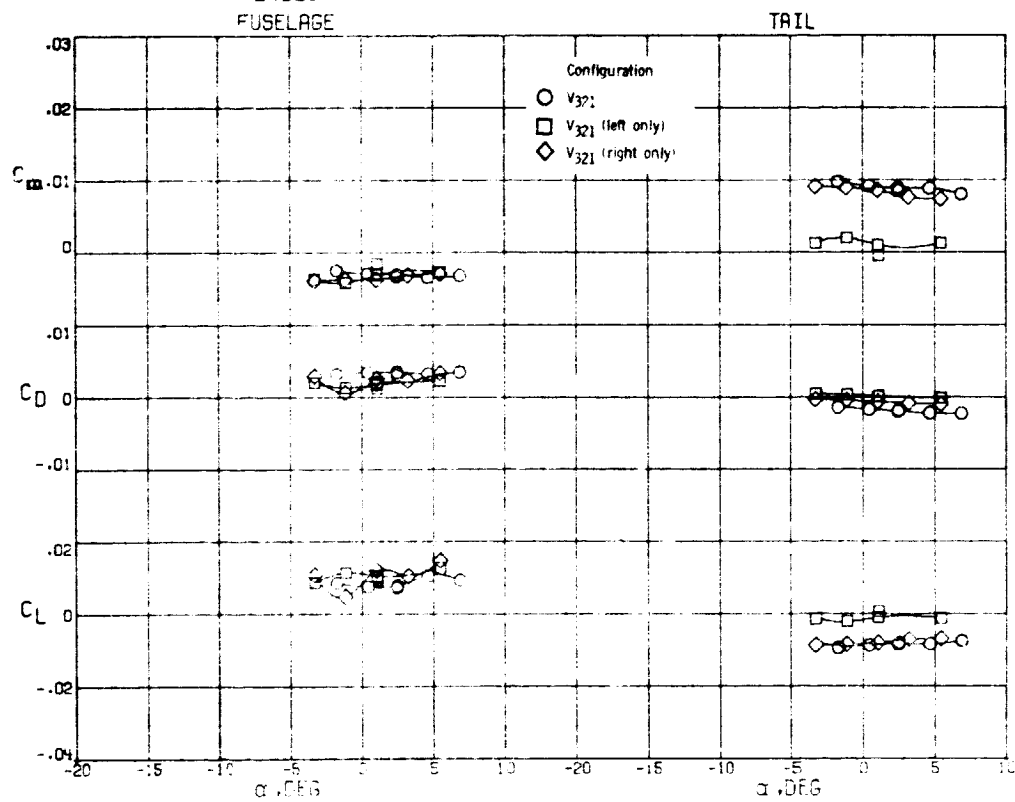
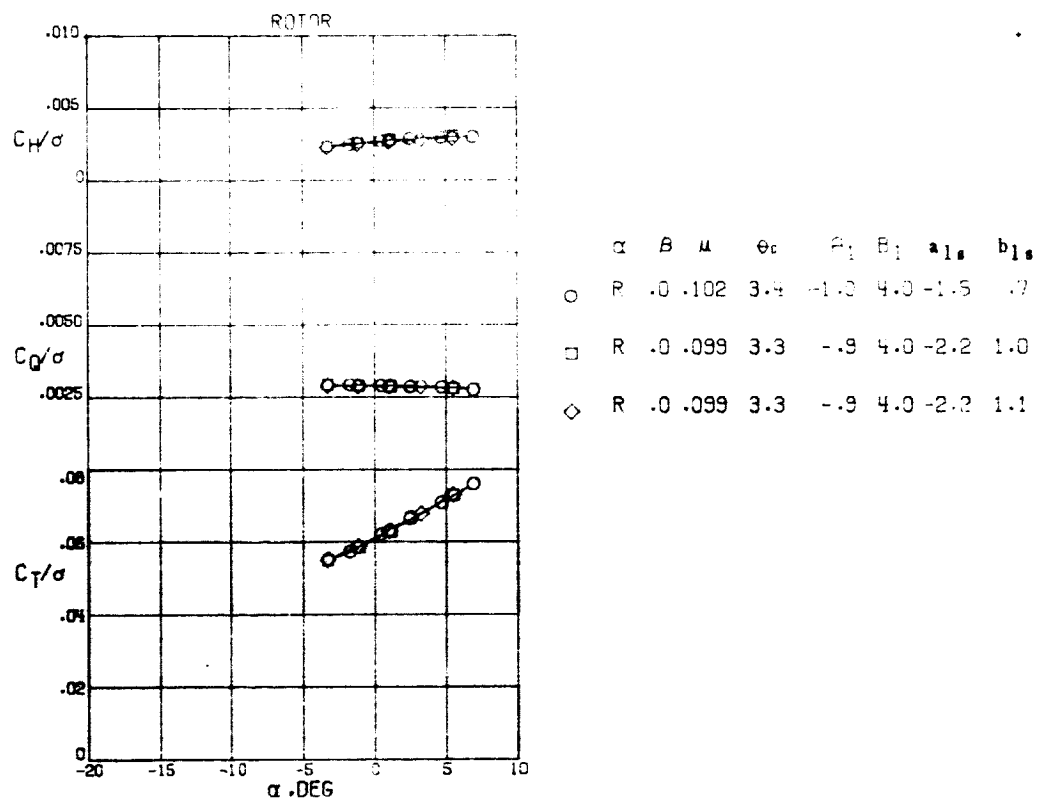
	α	β	μ	θ_c	a_1	b_1	a_{1s}	b_{1s}
○	R	.0	.056	4.6	-.9	3.7	-2.3	1.1
□	R	.0	.055	4.6	-.9	3.7	-2.4	1.4
◇	R	.0	.055	4.6	-.9	3.8	-2.4	1.4

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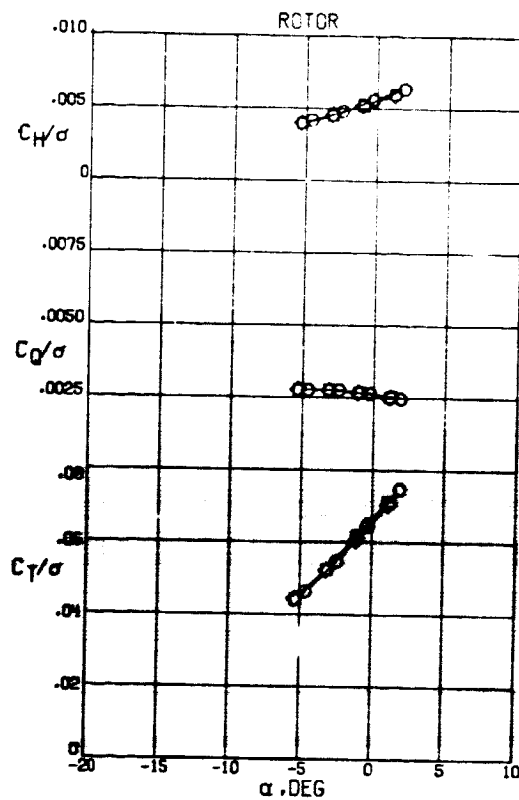
$\mu = 0.057$

Figure 11. - Comparison of the longitudinal aerodynamic characteristics of the baseline V-tail with the right or left tail surfaces removed.

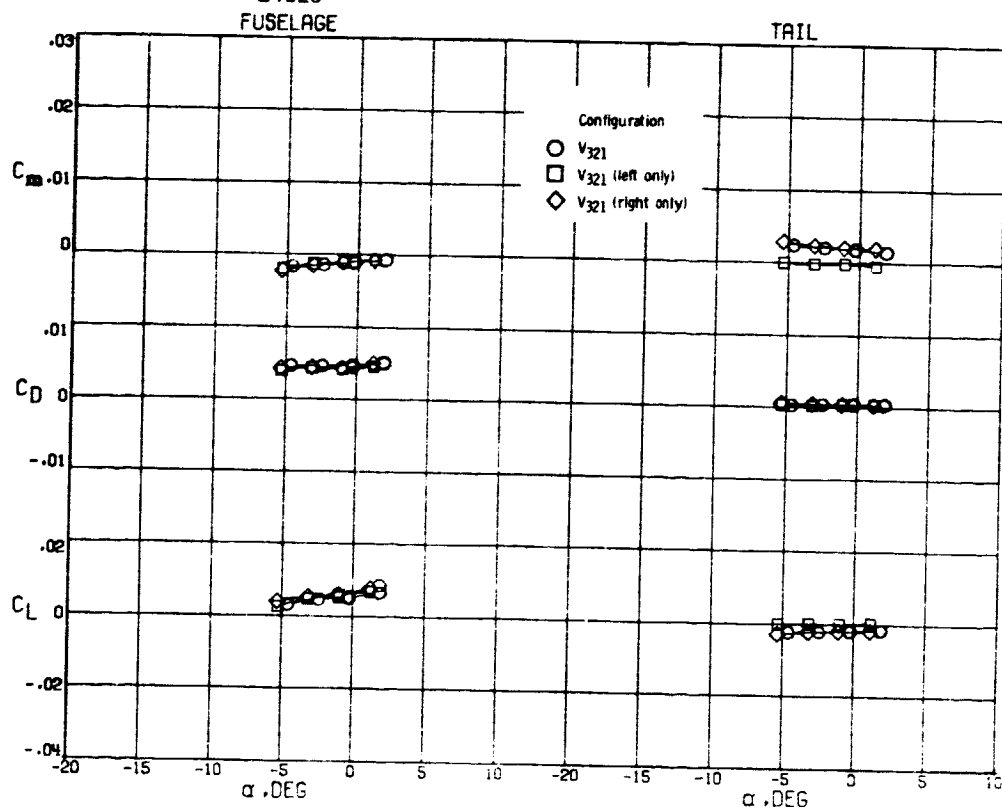


$\mu = 0.102$

Figure 11. - Continued.

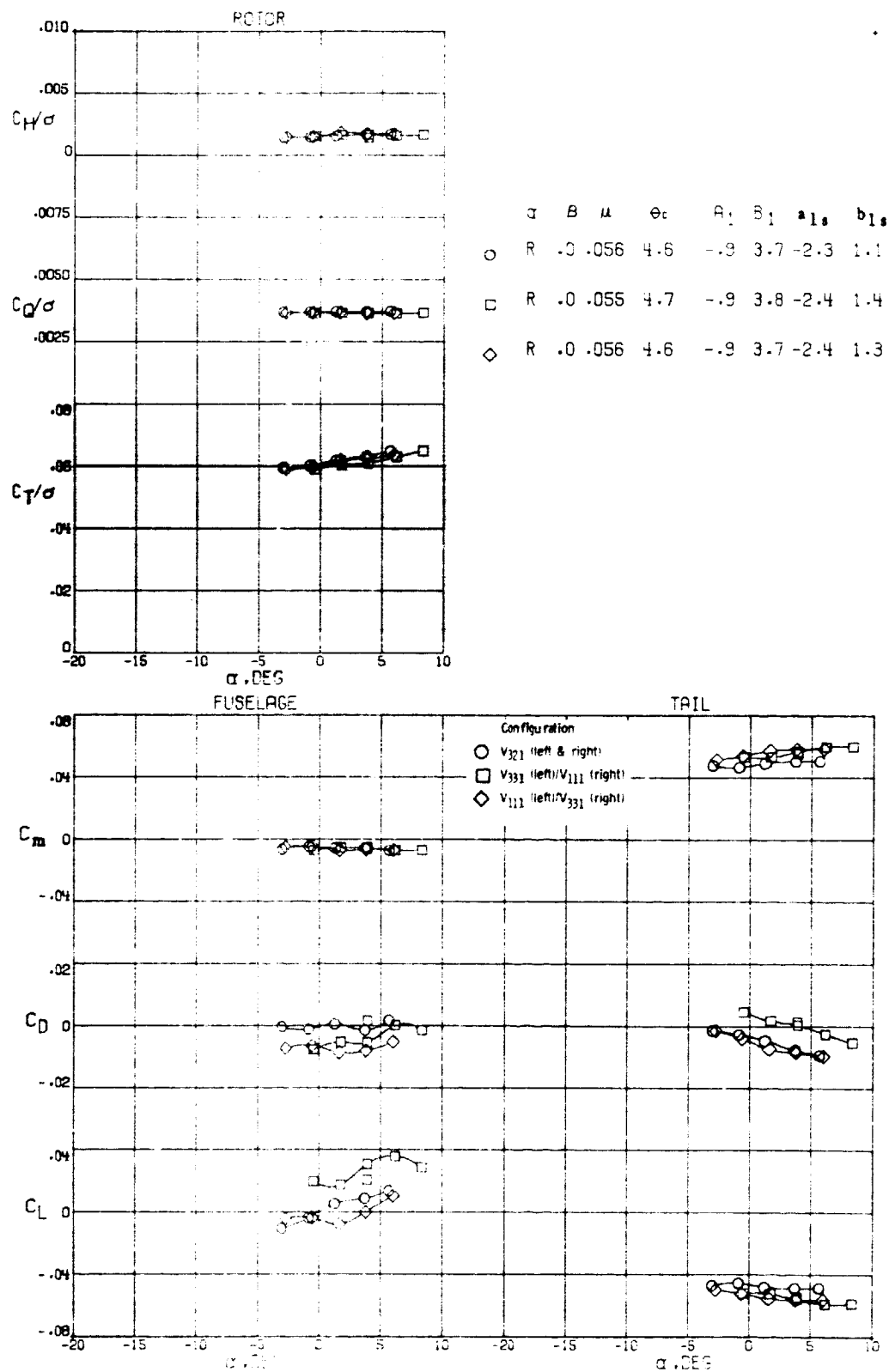


	α	B	μ	θ_c	ρ_1	B_1	a_{1s}	b_{1s}
○	R	.0	.193	3.2	-1.0	4.6	-.9	.2
□	R	.0	.187	3.2	-.9	4.6	-1.6	.5
◇	R	.0	.187	3.2	-.9	4.6	-1.4	.4



(c) $\mu = 0.192$

Figure 11. - Concluded.



$\mu = 0.057$

Figure 12.- Comparison of the impulsive aerodynamic characteristics of the baseline V-tail with two no system tail configurations.

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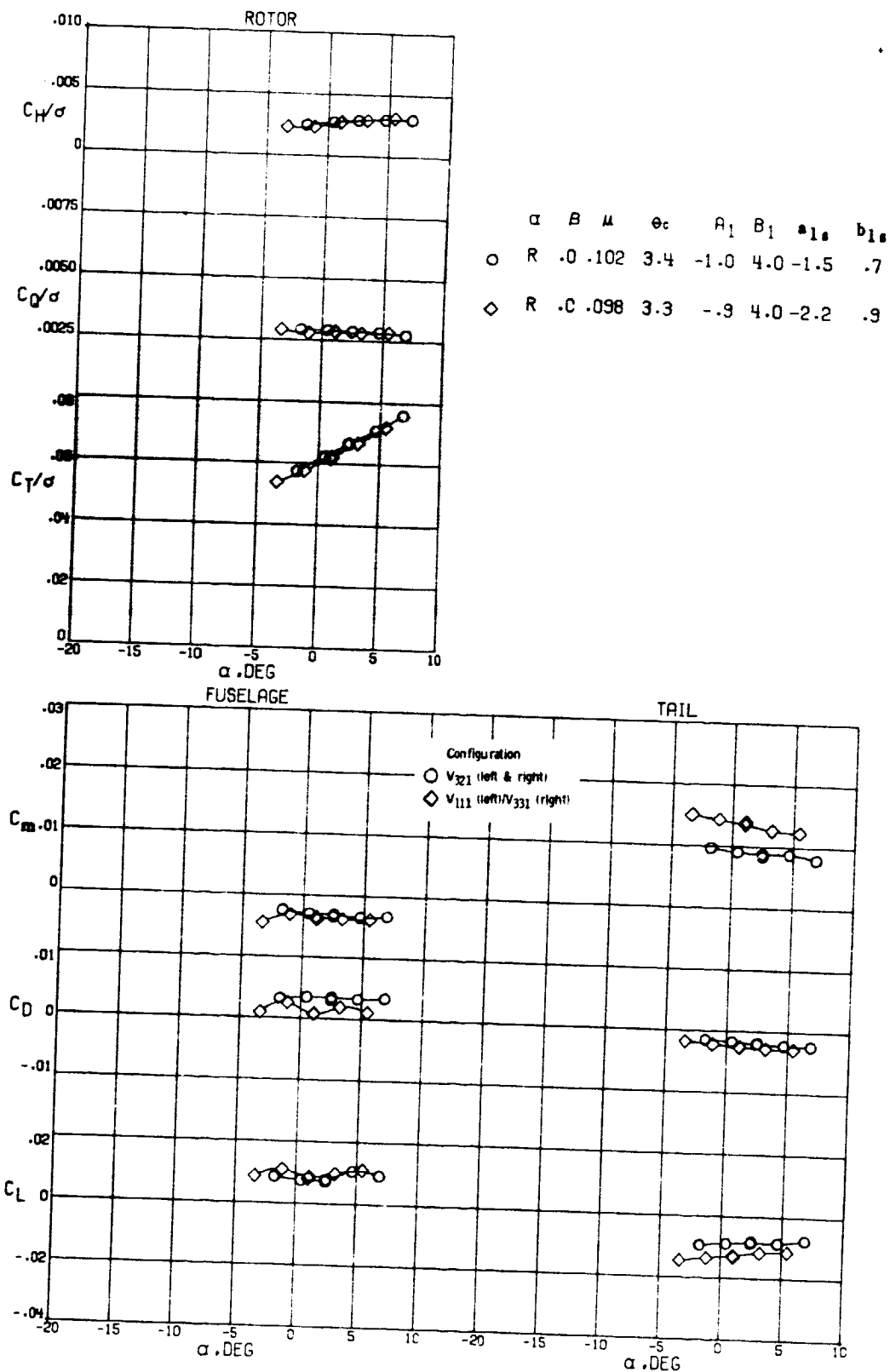
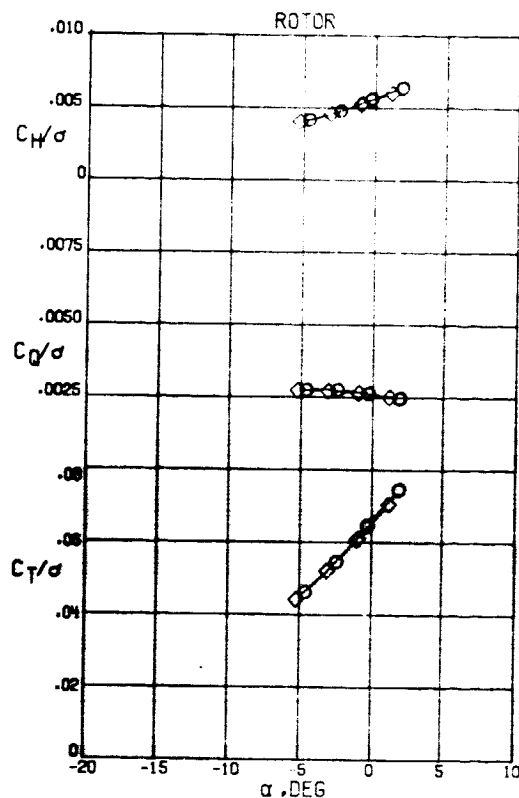


Figure 12.- Continued.

(b) $\mu = 0.102$



	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○ R	.0	.193	3.2	-1.0	4.6	-.9	.2
◇ K	.0	.187	3.2	-.9	4.6	-1.5	.4

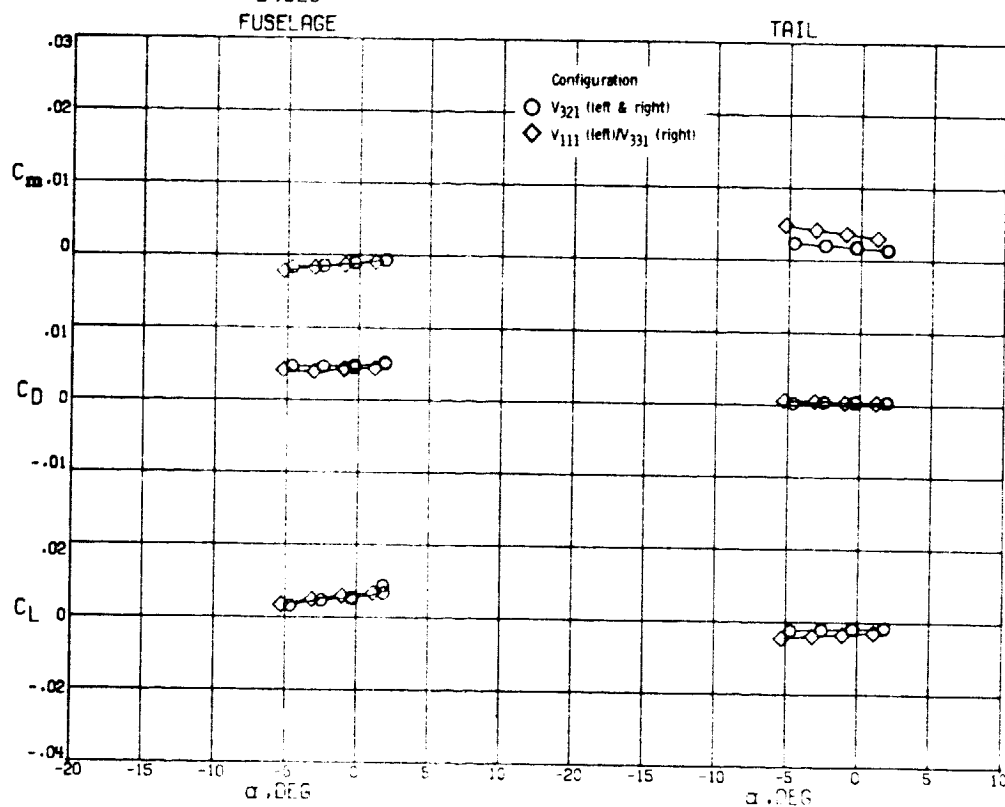
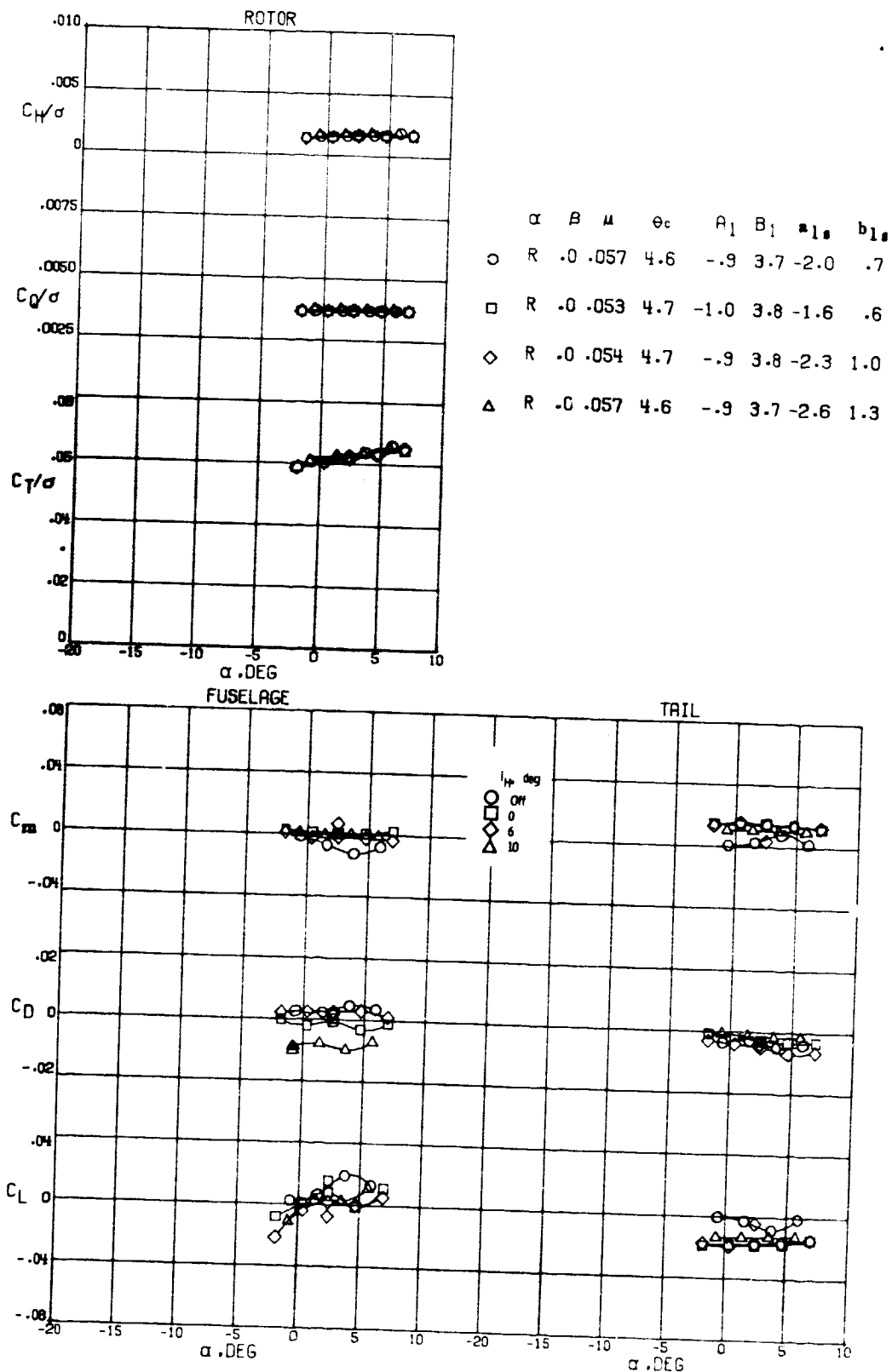


Figure 12. - Concluded.

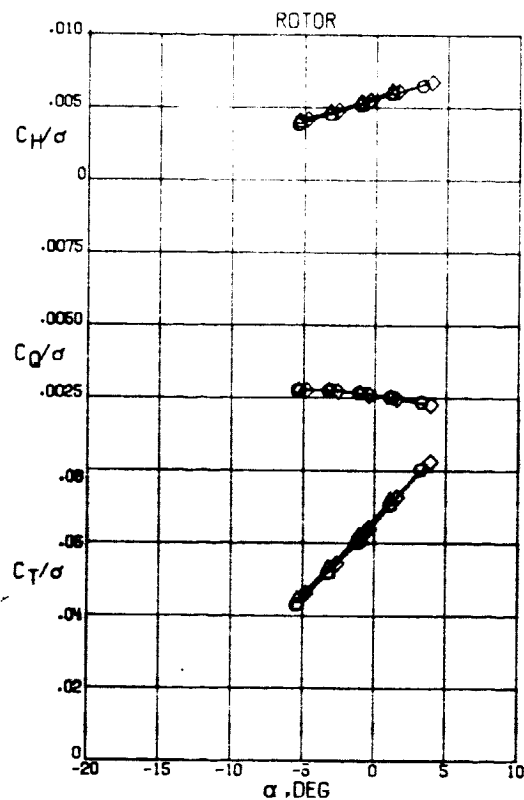
(c) $\mu = 0.192$

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(a) $\mu = 0.057$

Figure 13.- Effect of horizontal tail (conventional) incidence on the longitudinal aerodynamic characteristics of the model.



	α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	R	.0	.190	3.2	-.9	4.6	-1.4	.3
□	R	.0	.190	3.2	-.9	4.6	-1.4	.2
◇	R	.0	.190	3.2	-1.0	4.6	-1.4	.4
△	R	.0	.190	3.2	-1.0	4.6	-1.4	.3

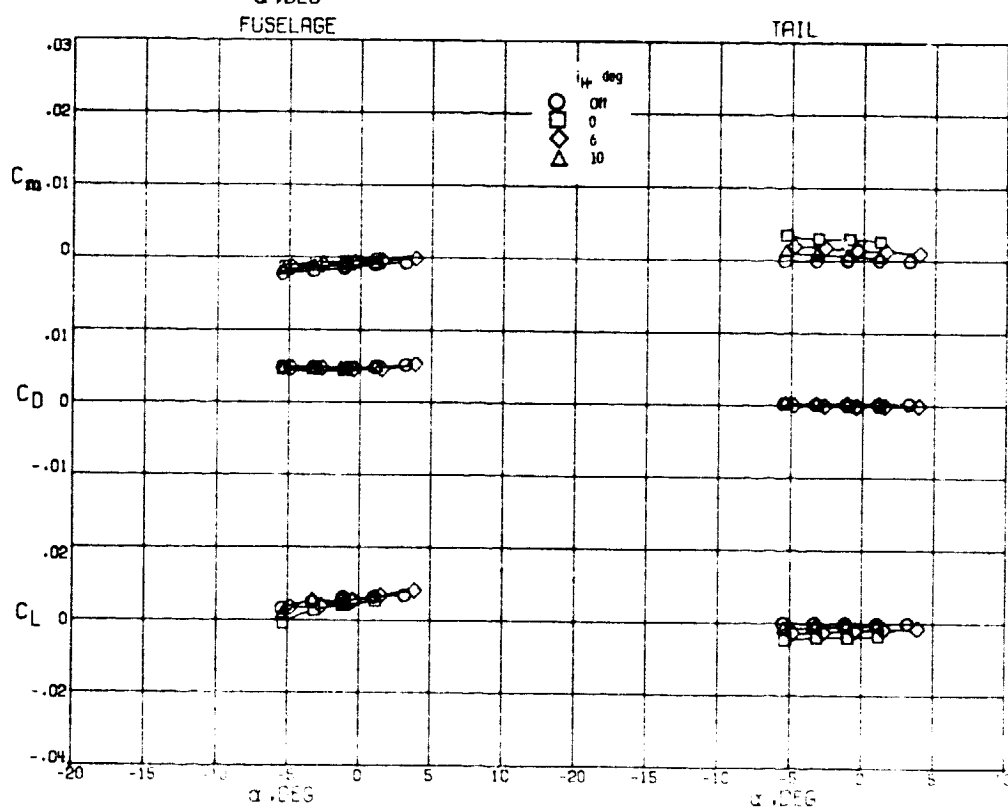
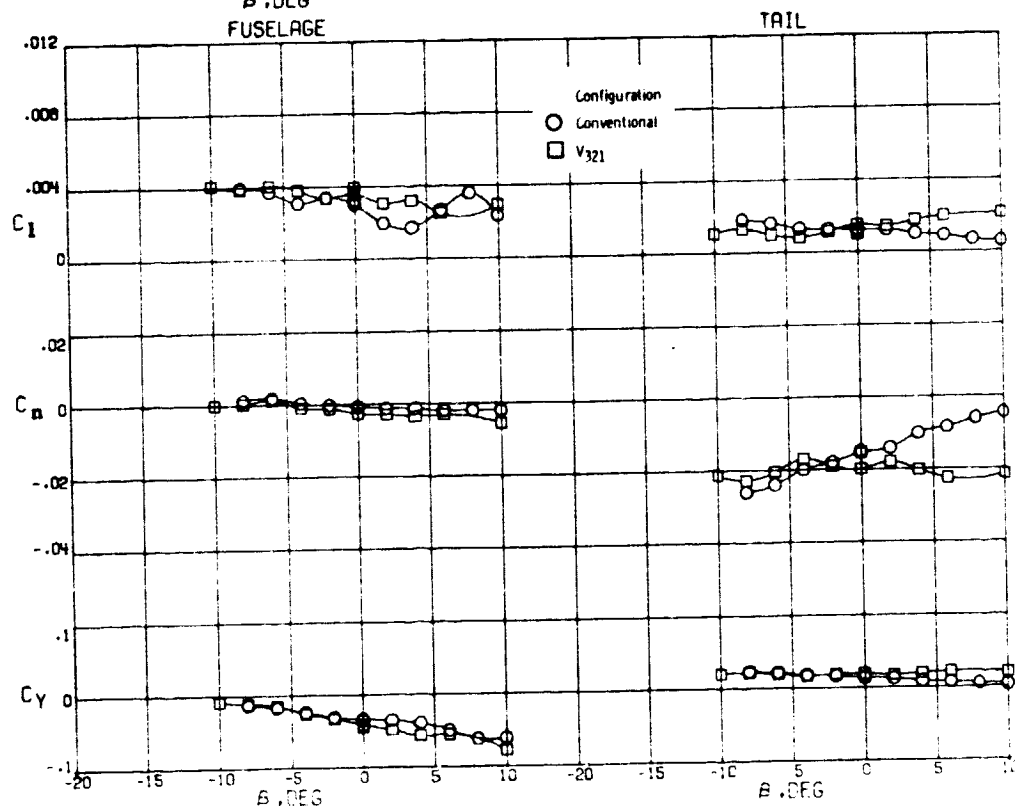
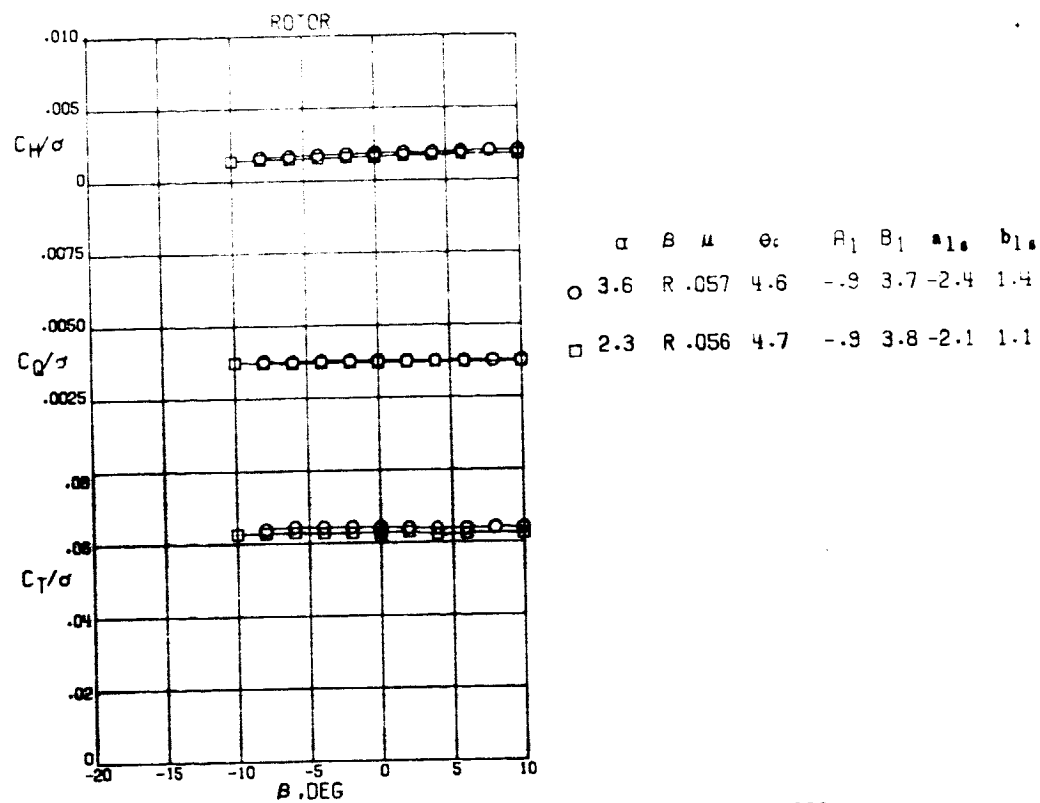


Figure 13.- Concluded.

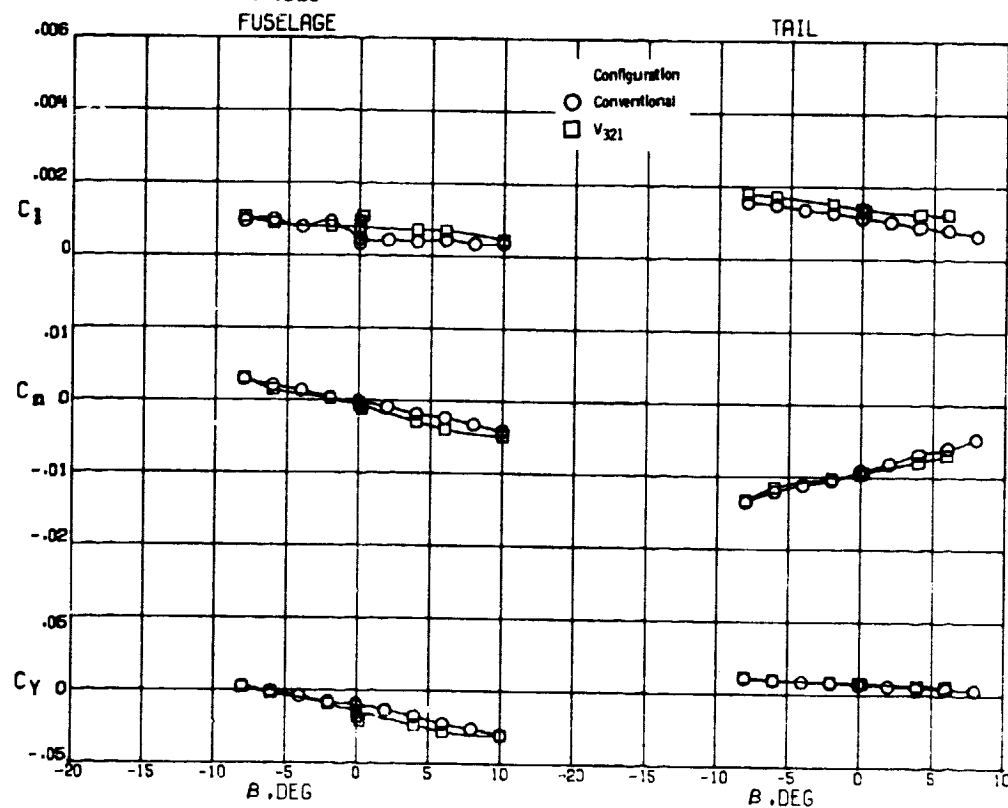
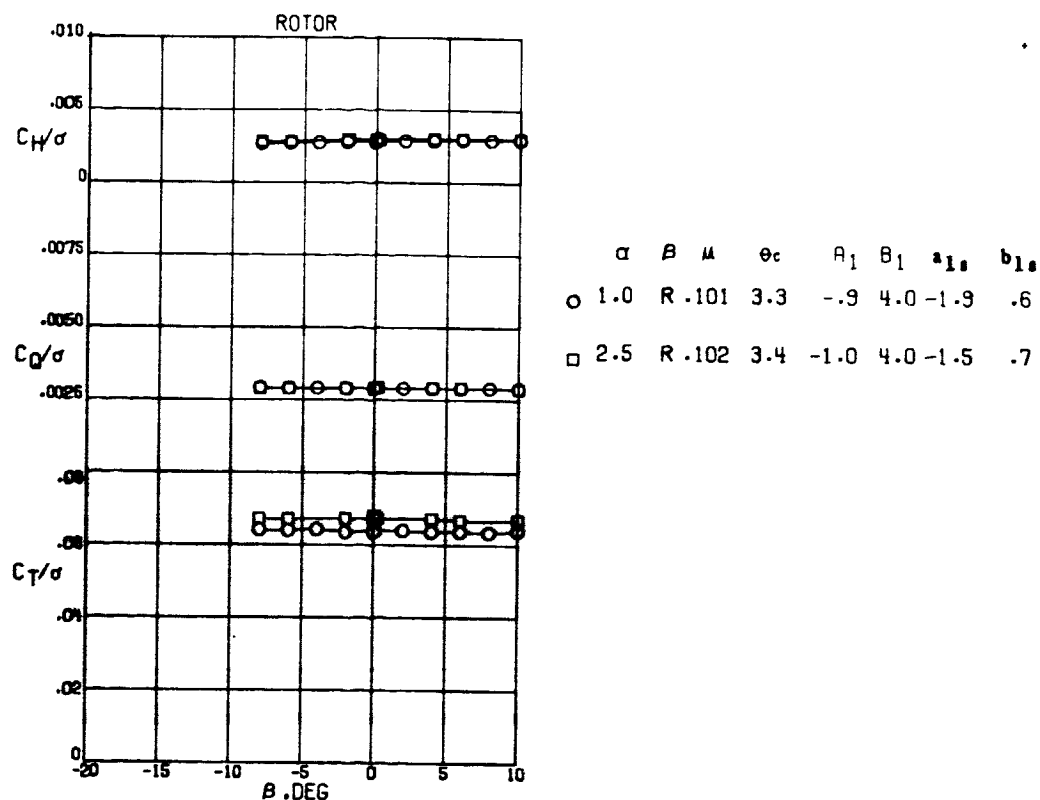
(b) $\mu = 0.192$

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(a) $\mu = 0.057$

Figure 14.- Lateral-directional characteristics of the conventional tail and the baseline V-tail in 1-g flight at three advance ratios.



(b) $\mu = 0.102$

Figure 14 - Continued.

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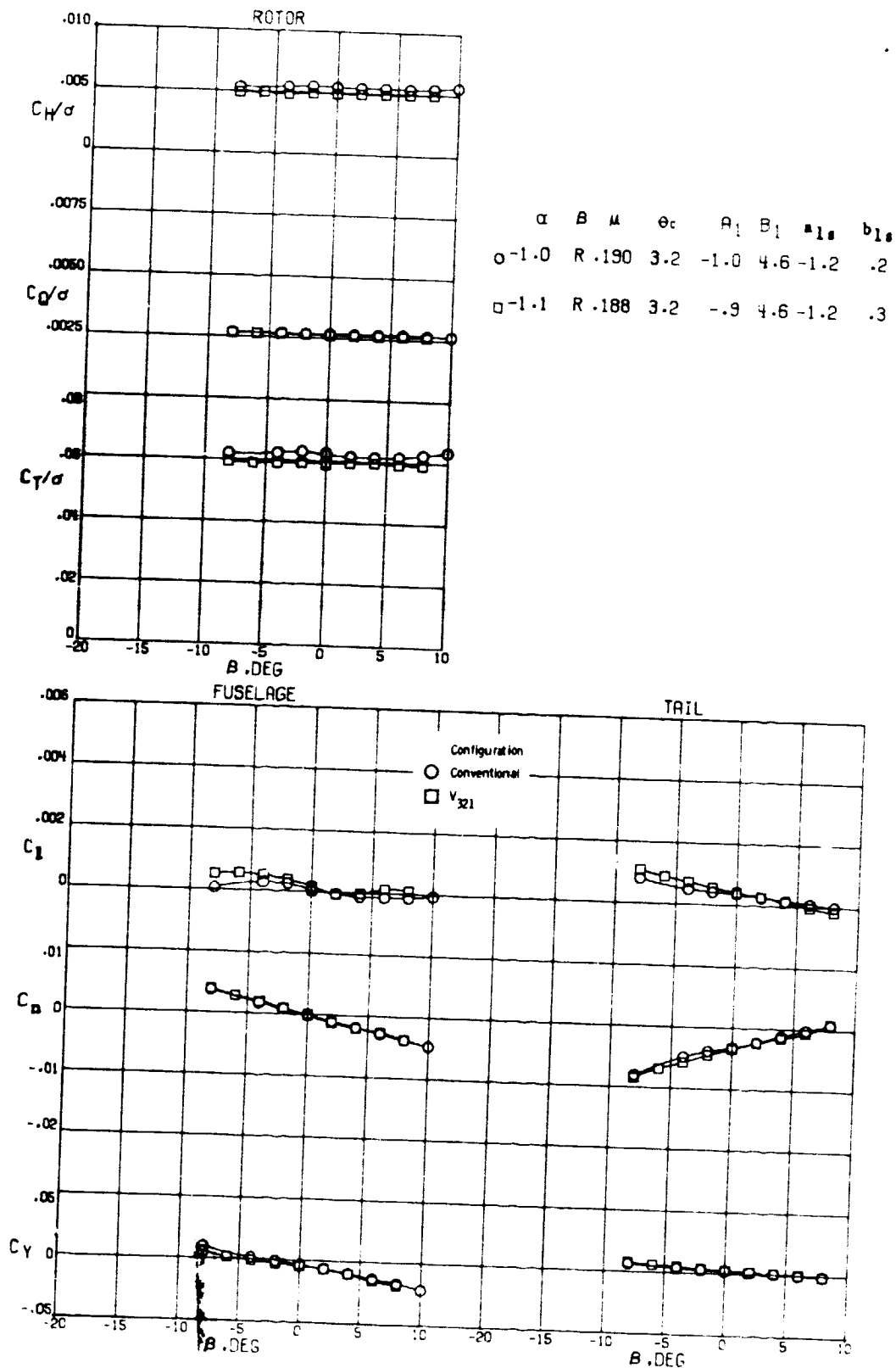
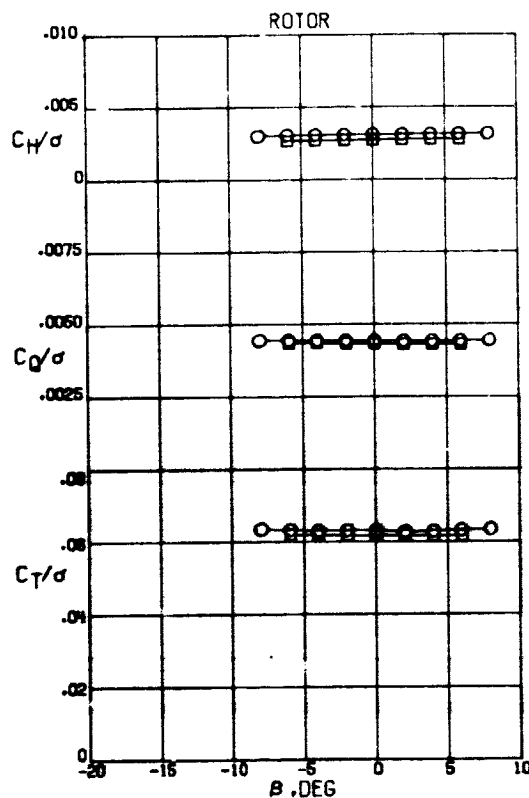
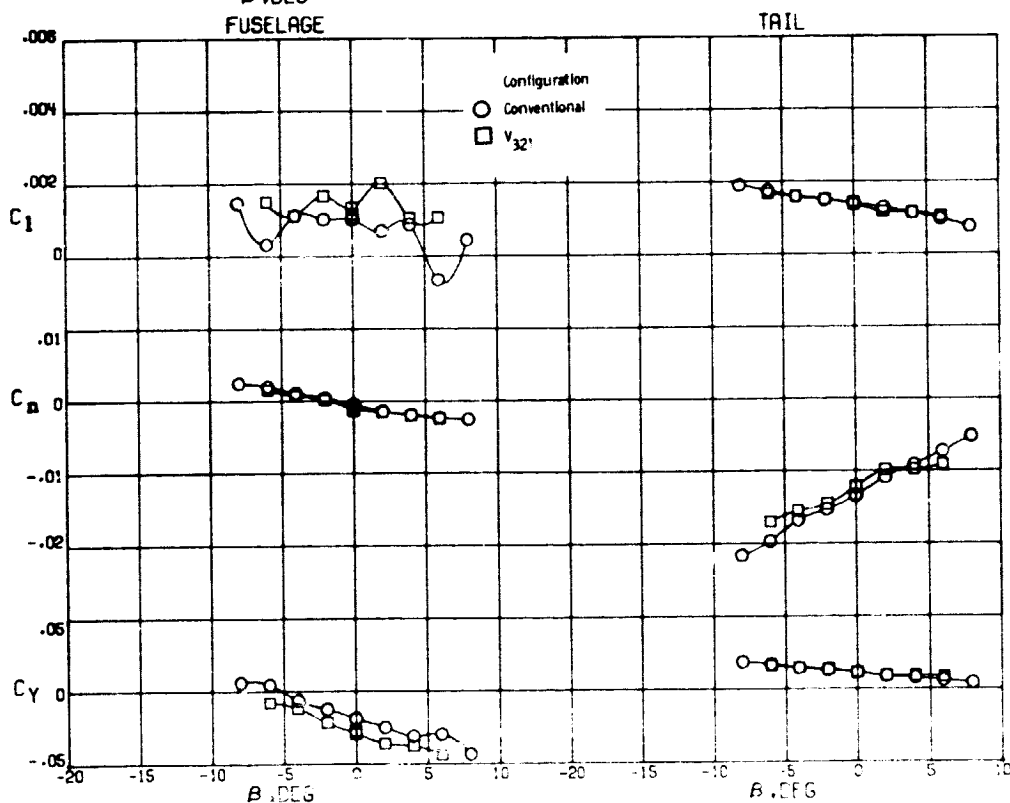


Figure 14- Concluded.



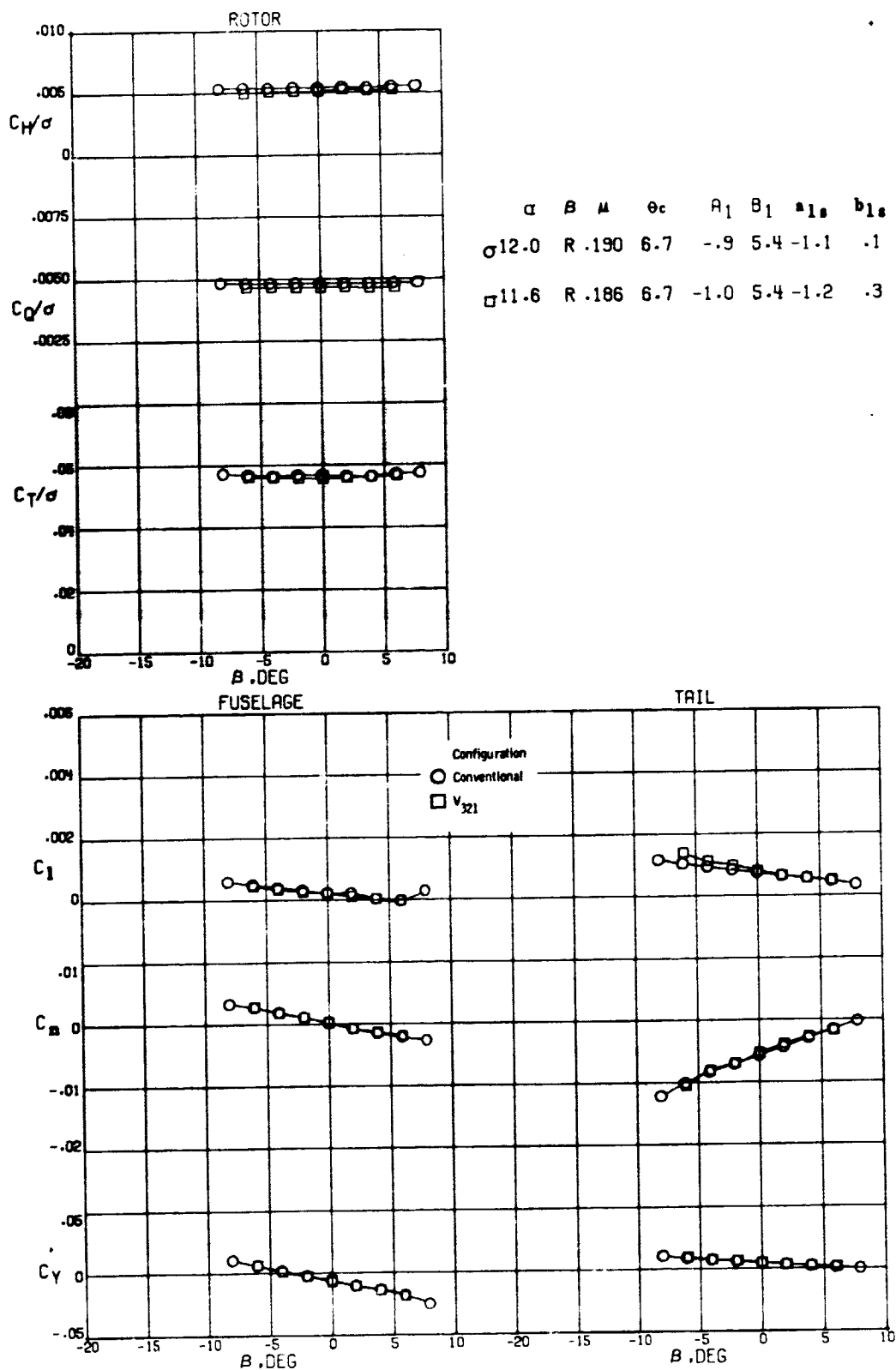
α	β	M	θ_c	A_1	B_1	a_1	b_1
12.7	R	.100	5.7	-.9	3.9	-1.6	.3
12.9	R	.099	5.7	-.9	3.9	-1.5	.4



(a) $M = 0.102$

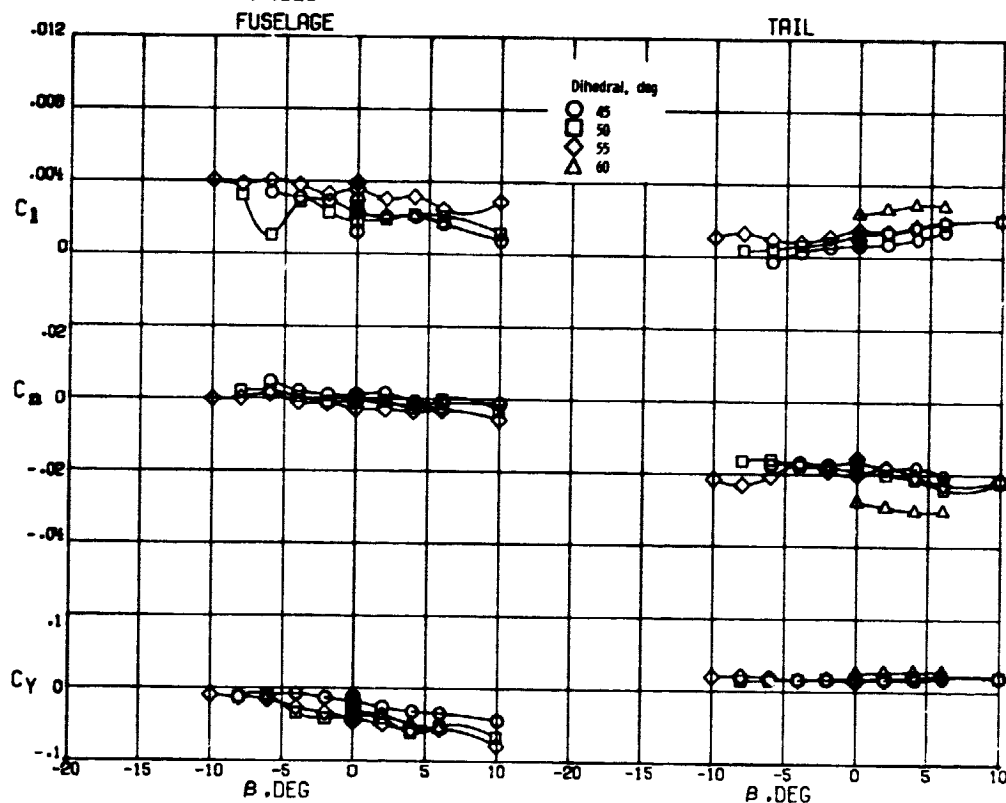
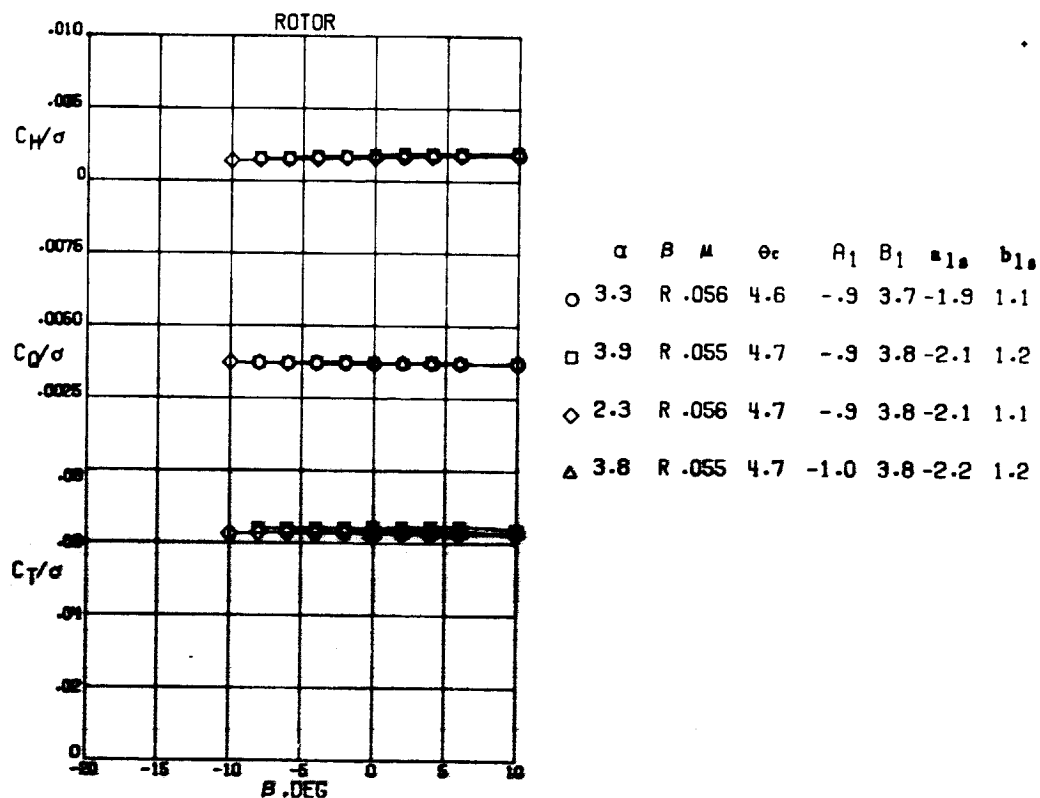
Figure 15.- Lateral-directional characteristics of the conventional tail and the baseline V-tail in climb at two advance ratios.

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(b) $M = 0.192$

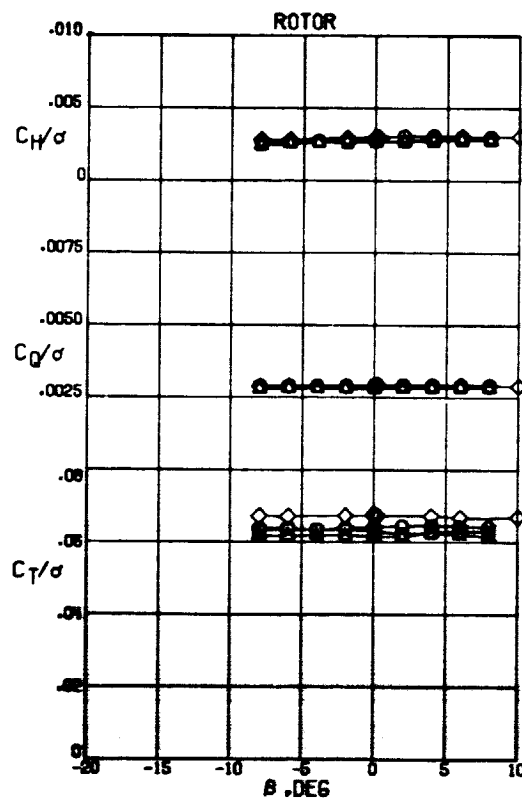
Figure 15. - Concluded.



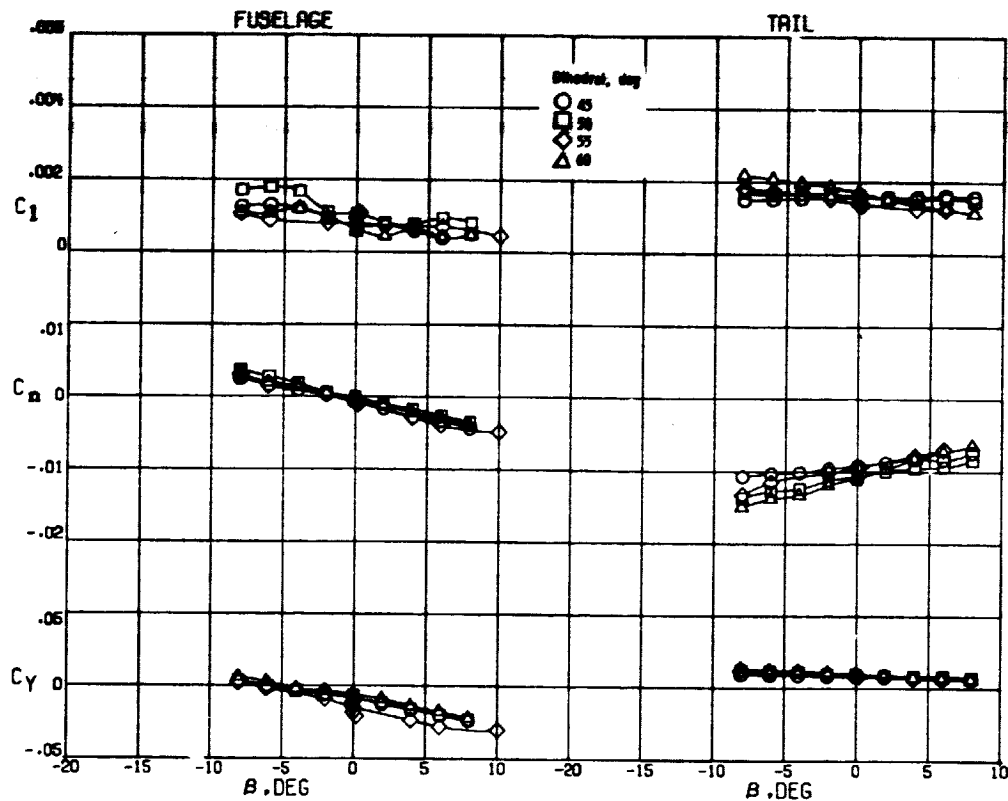
(a) $\mu = 0.057$

Figure 16. - Effect of V-tail dihedral on the lateral-directional characteristics of the model at three advance ratios.

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α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	1.0	R .099	3.3	-.9	4.0	-2.1	1.0
□	.9	R .098	3.3	-.9	3.9	-2.1	1.0
◇	2.5	R .102	3.4	-1.0	4.0	-1.5	.7
△	1.0	R .099	3.4	-.9	4.0	-2.1	1.0



(b) $\mu = 0.102$

Figure 16 - Continued.

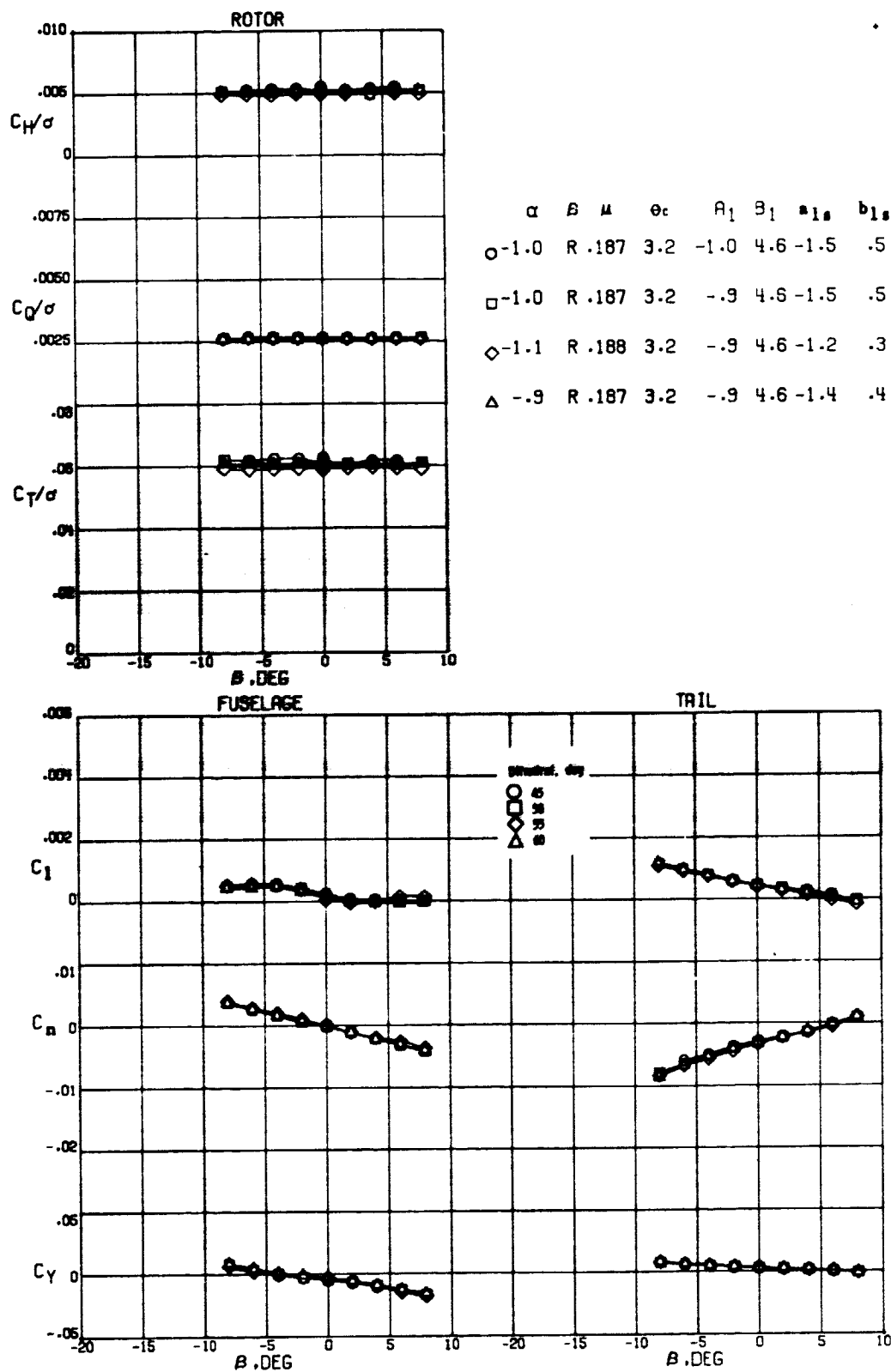
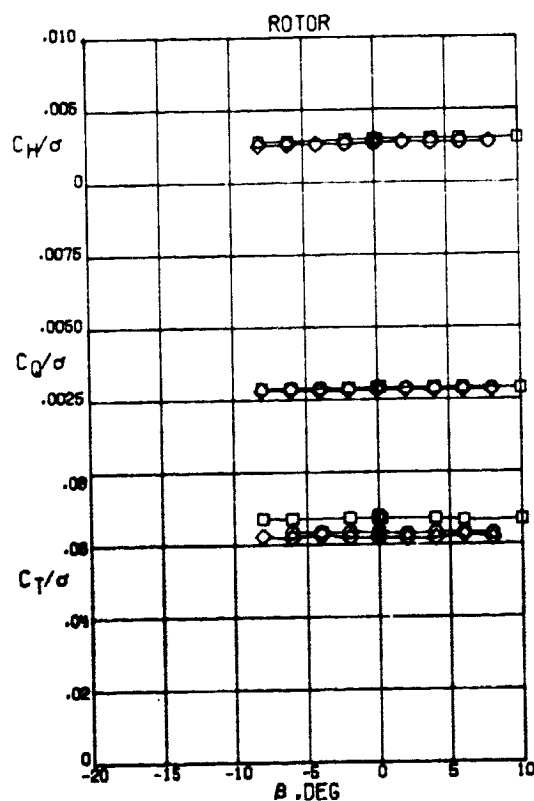
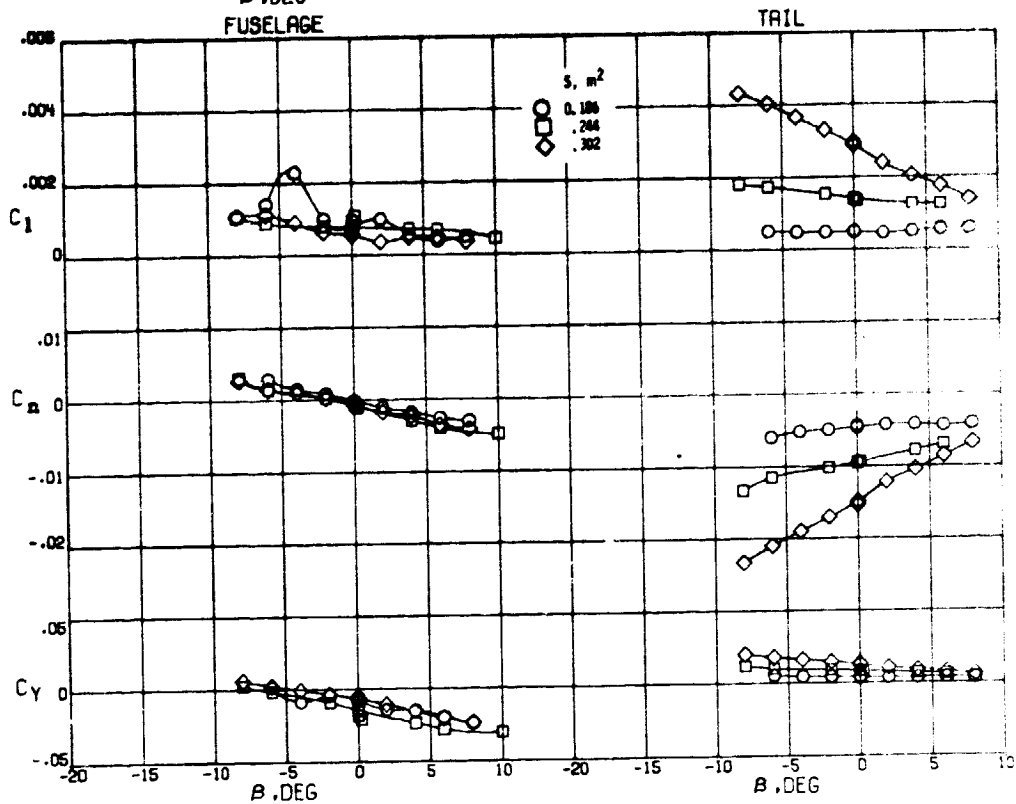


Figure 16.- Concluded.

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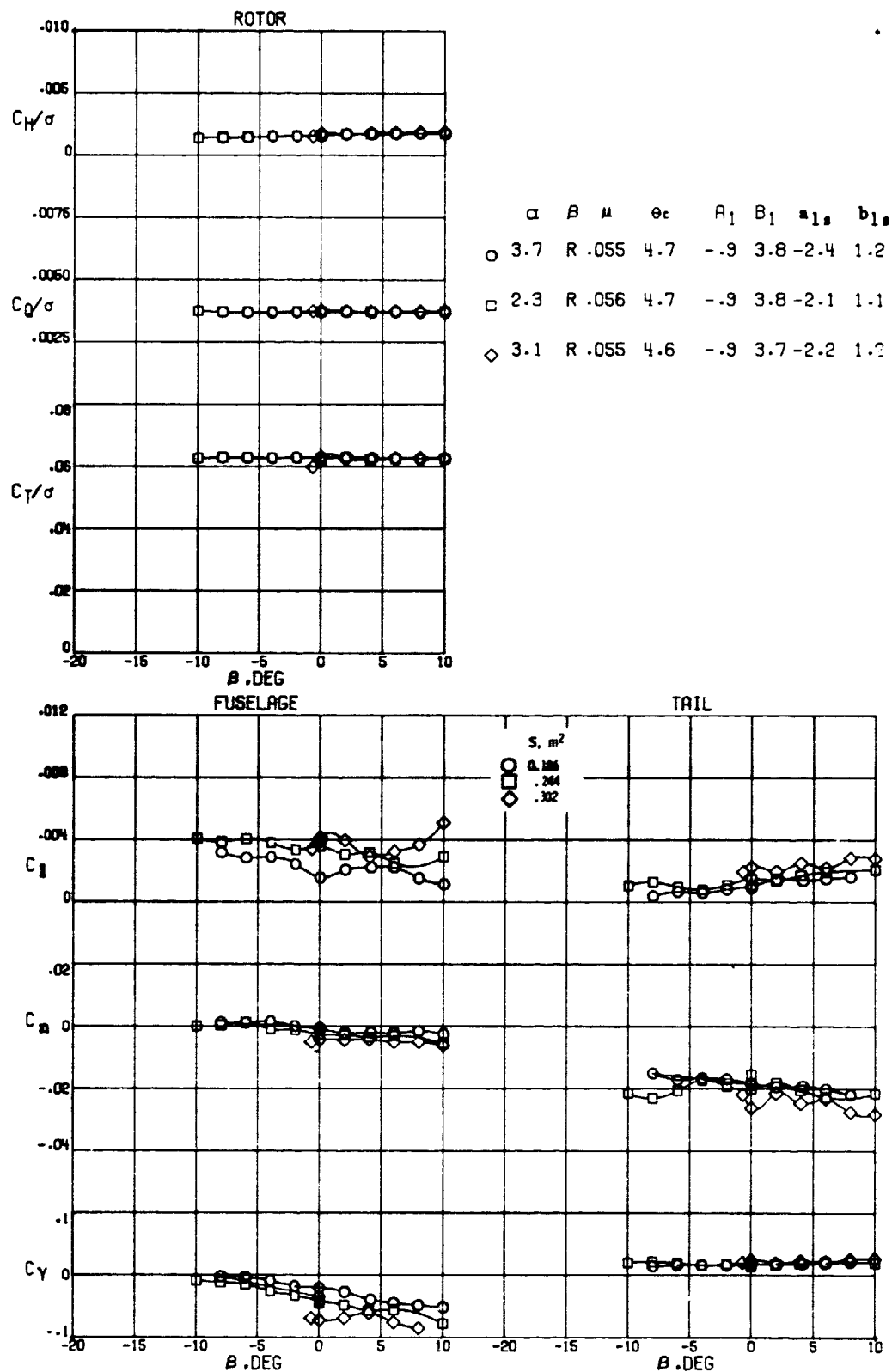


	α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	1.0	R .098	3.3	-1.0	3.9	2.2	.9	
□	2.5	R .102	3.4	-1.0	4.0	1.5	.7	
◇	1.0	R .099	3.3	-1.0	4.0	-2.2	.9	



(b) $\mu = 0.102$

Figure 17.- Continued.



(a) $\mu = 0.057$

Figure 17.- Effect of V-tail planform area on the lateral-directional characteristics of the model at three advance ratios.

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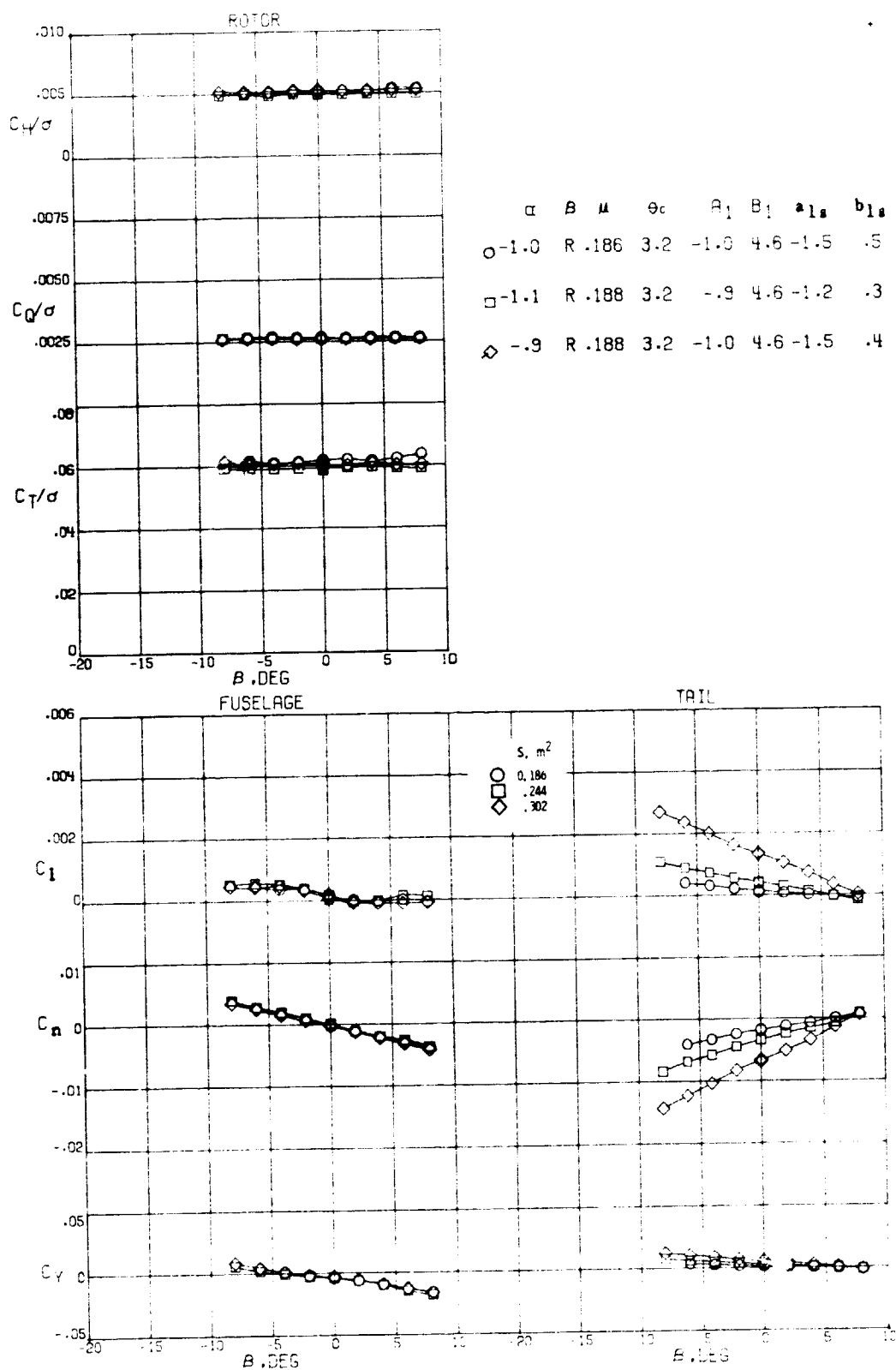
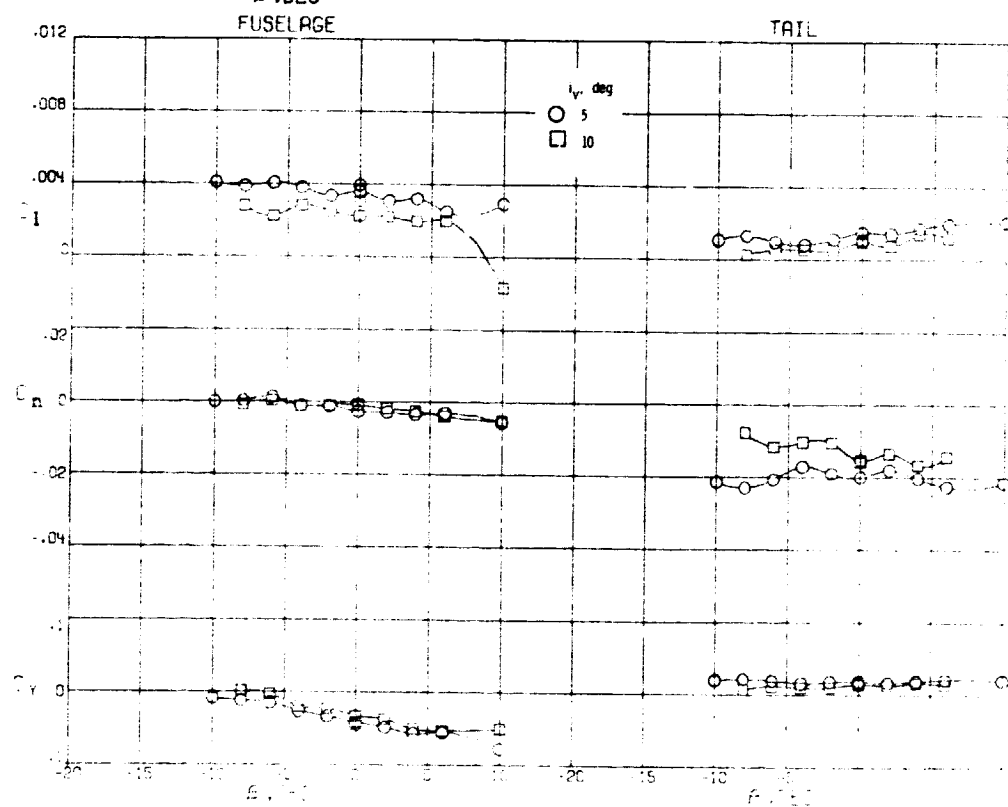
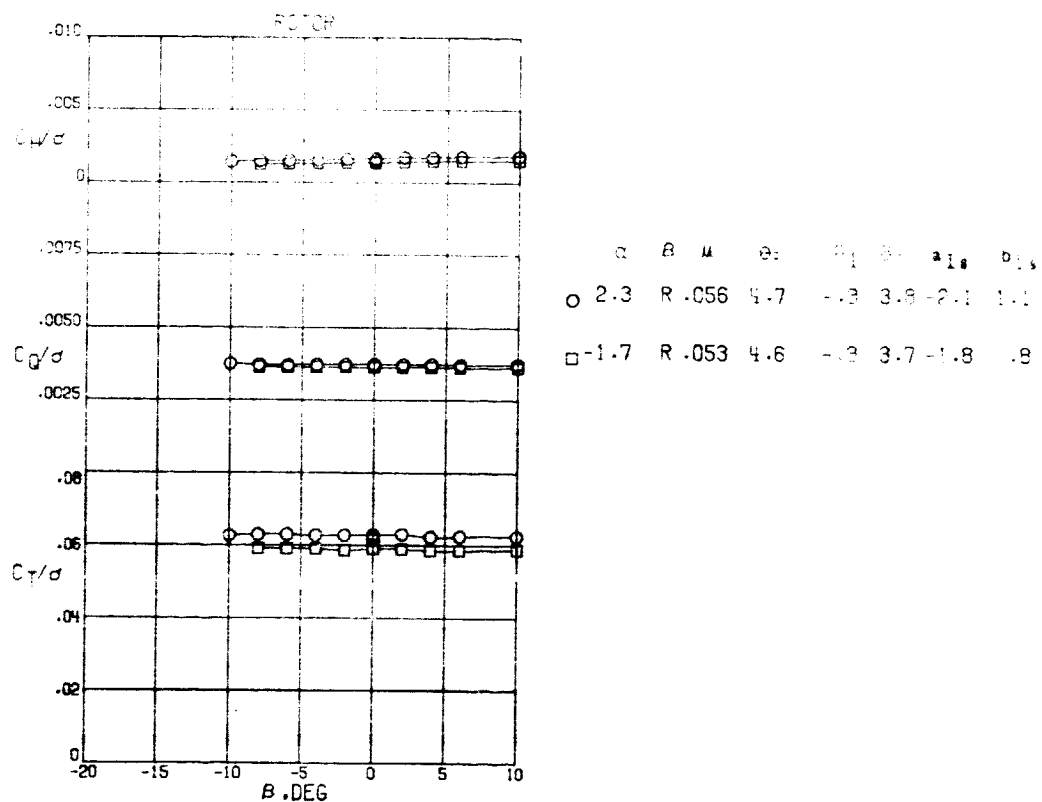


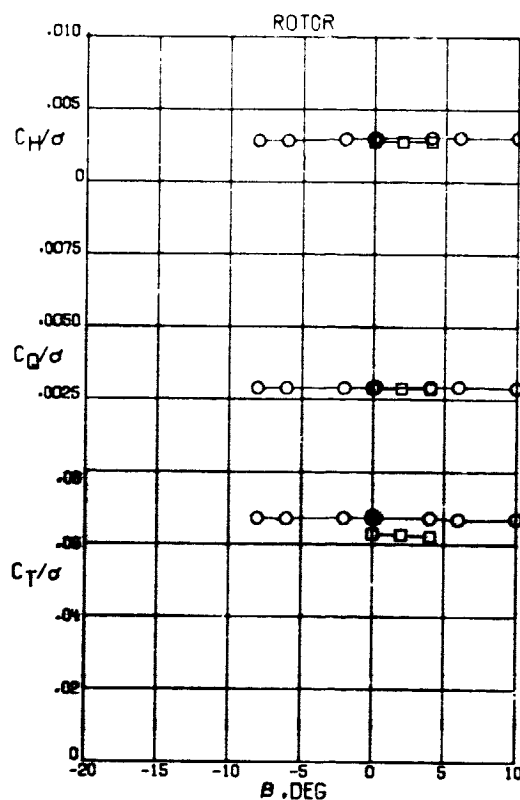
Figure 17.- Concluded.



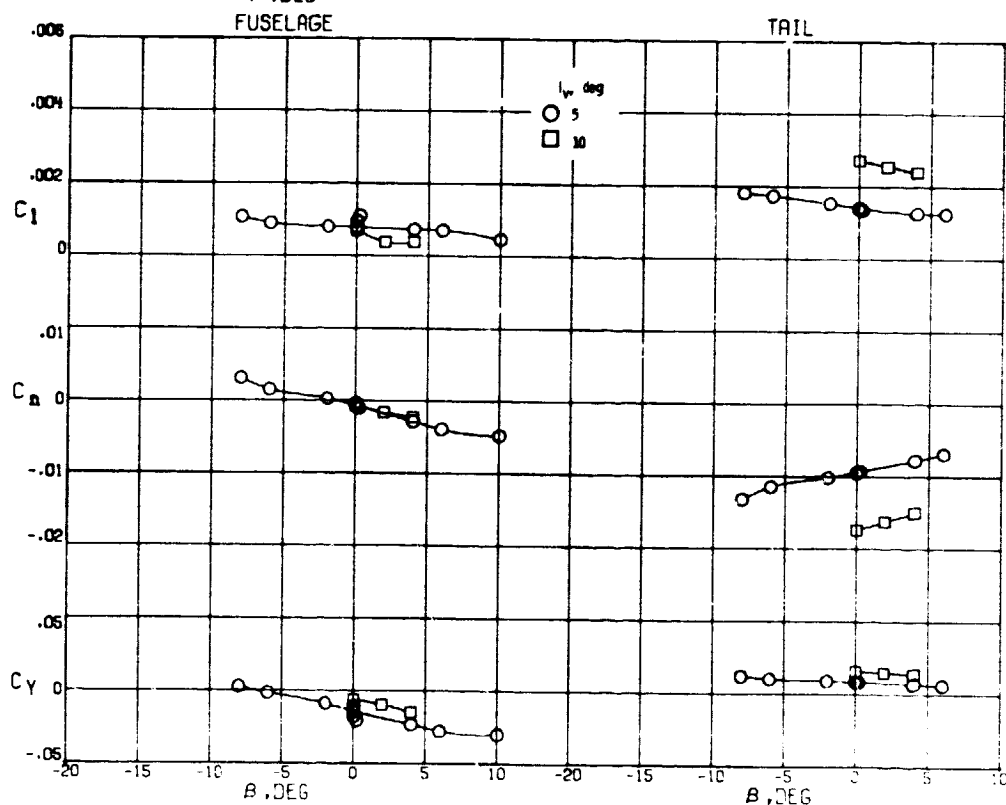
(a) $M = 0.057$

Figure 18.- Effect of angle of incidence on the aerodynamic characteristics of the model at three advance ratios.

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α	B	M	θ_c	A_1	B_1	a_{1s}	b_{1s}
○ 2.5	R .102	3.4	-1.0	4.0	-1.5	.7	
□ 1.0	R .099	3.3	-.9	4.0	-2.1	.9	



(b) $\mu = 0.102$

Figure 18. - Continued.

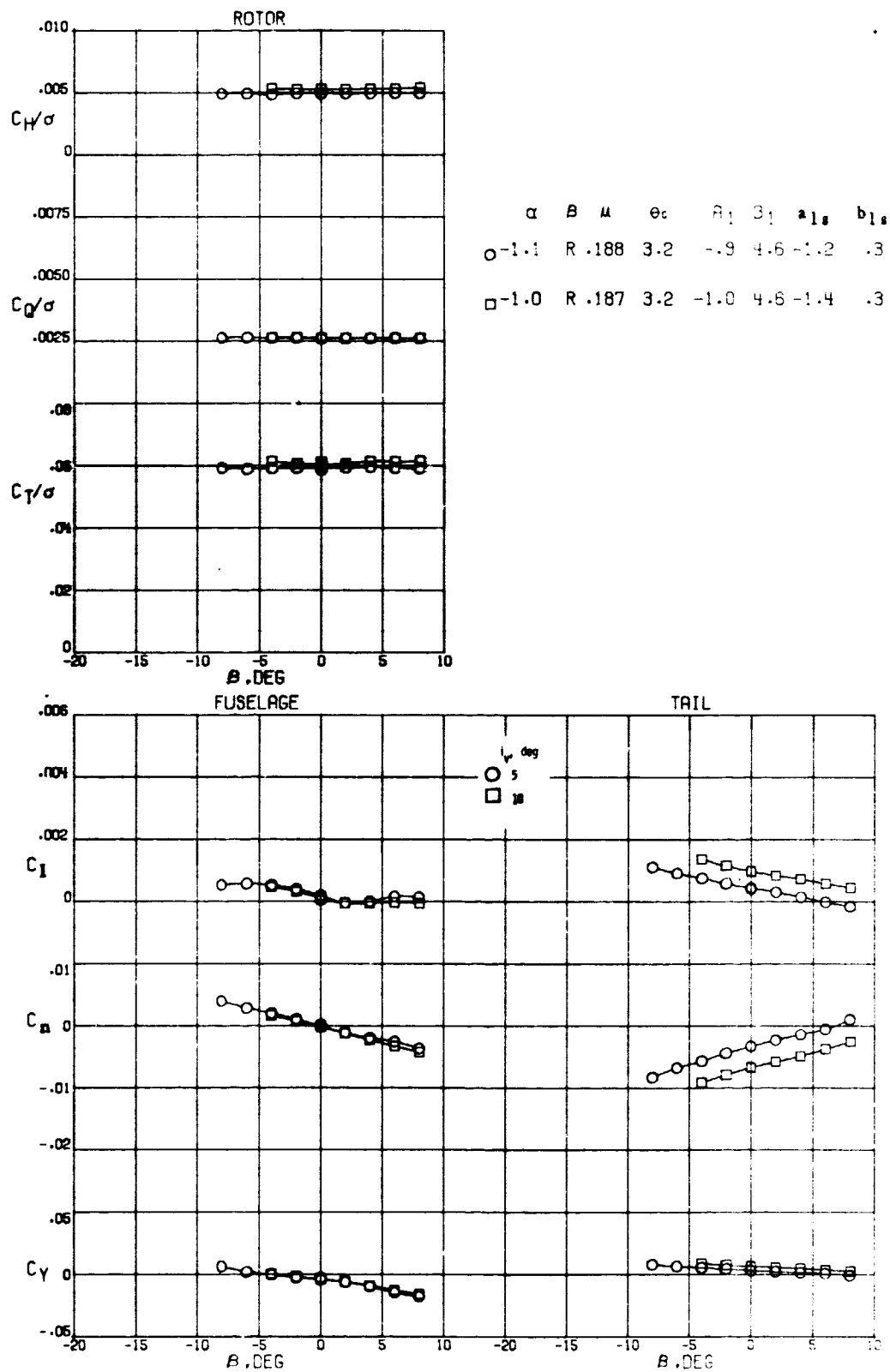
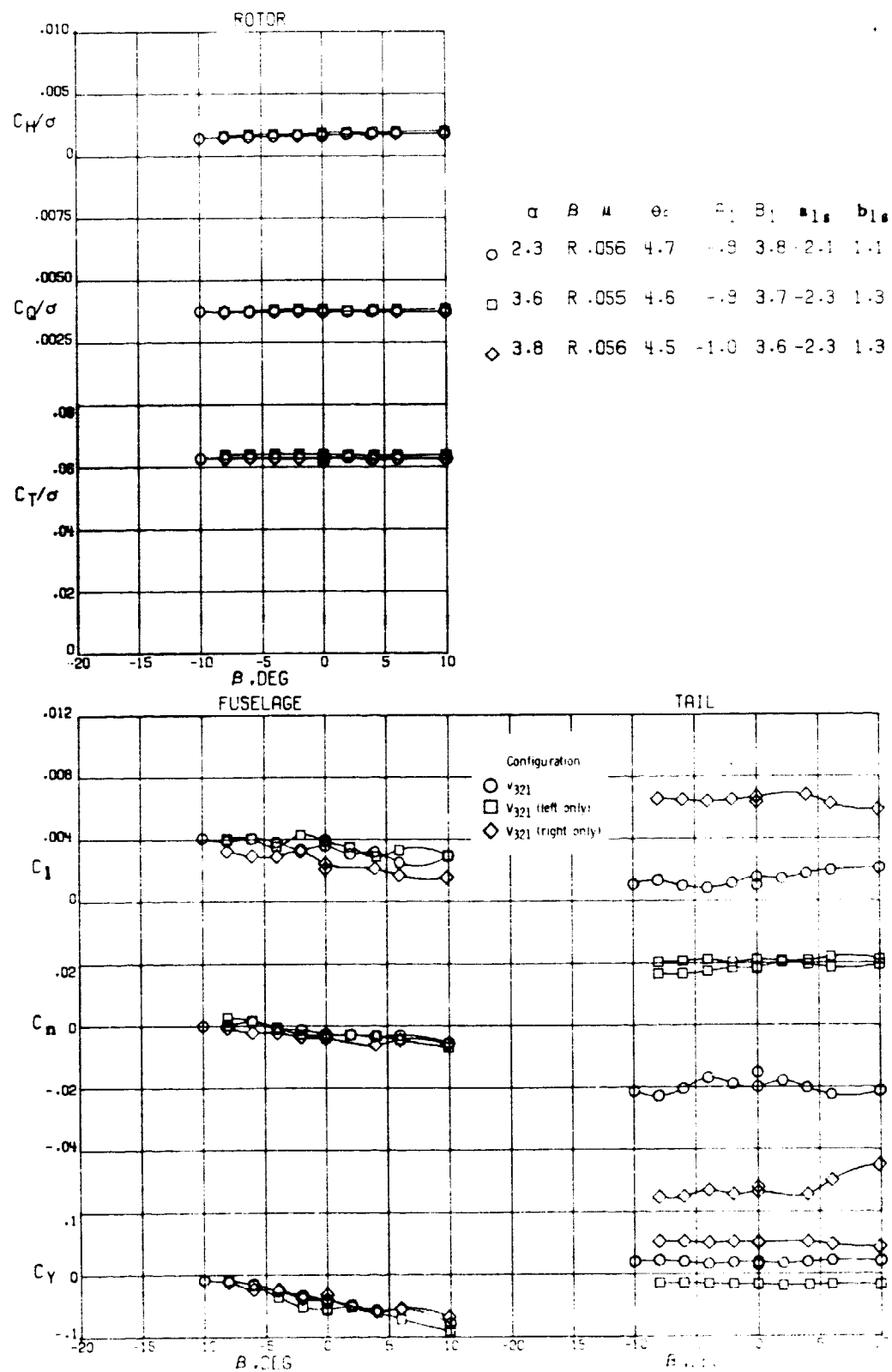


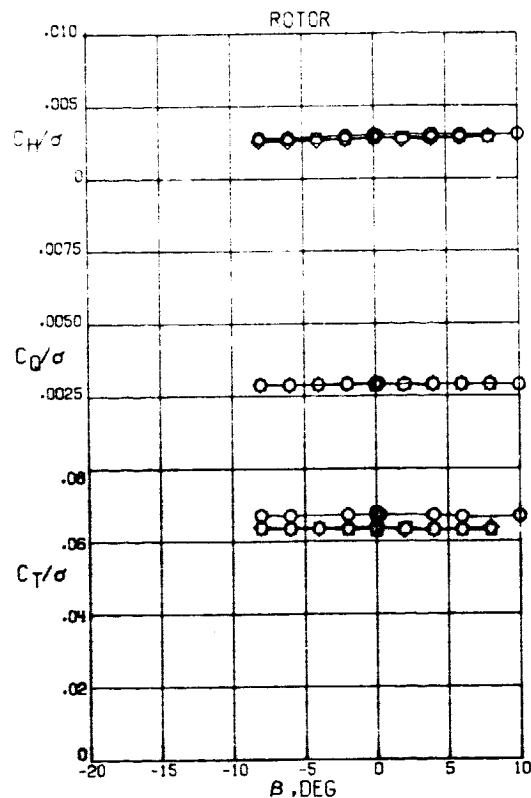
Figure 18.- Concluded.

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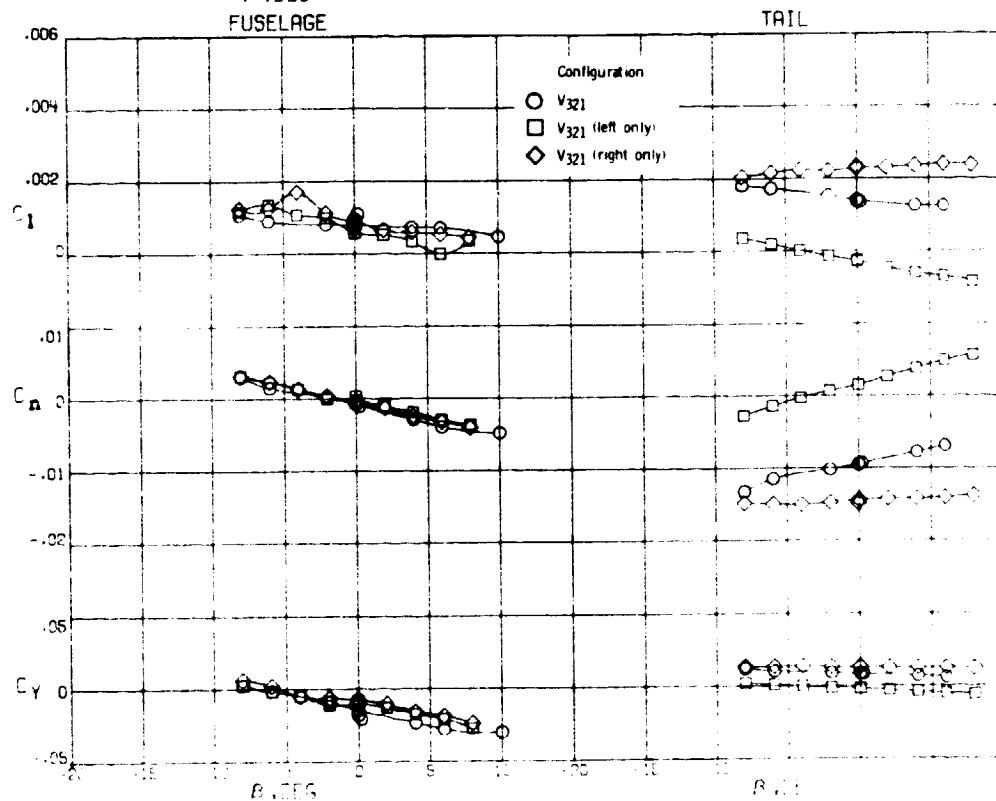


(a) $\mu = 0.057$

Figure 19. - Comparison of the lateral-directional characteristics of the baseline V-tail with the right or left tail surfaces removed.



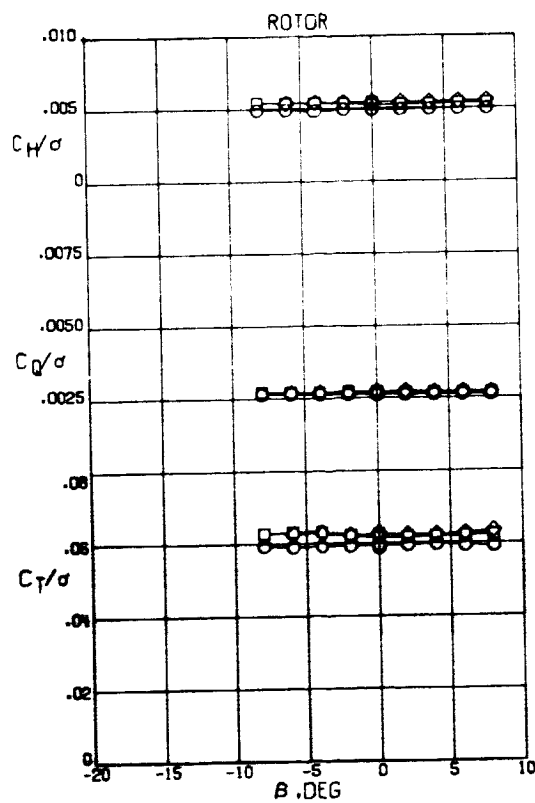
	α	B	u	θ_c	μ_1	B_1	a_{1s}	b_{1s}
○	2.5	R .102	3.4	-1.0	4.0	-1.5	.7	
□	1.0	R .099	3.3	-1.9	4.0	-2.2	1.0	
◇	1.0	R .099	3.3	-1.9	4.0	-2.1	1.0	



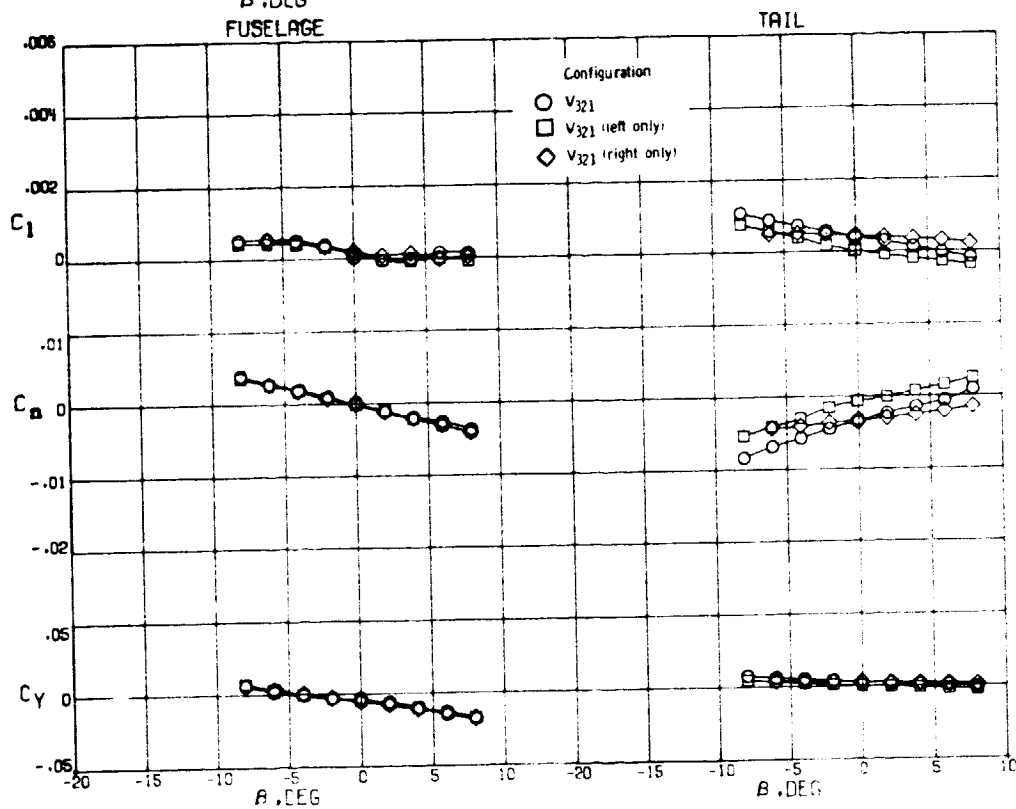
$\mu = 0.102$

Figure 9. - Continued.

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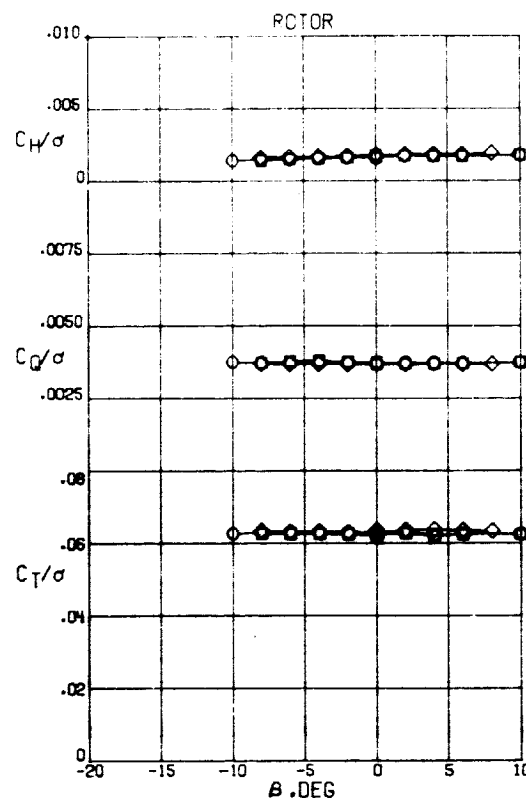


α	B	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○ -1.1	R .188	3.2	-.9	4.6	-1.2	.3	
□ -1.0	R .187	3.2	-.3	4.6	-1.5	.6	
◇ -1.0	R .187	3.2	-.9	4.6	-1.2	.5	

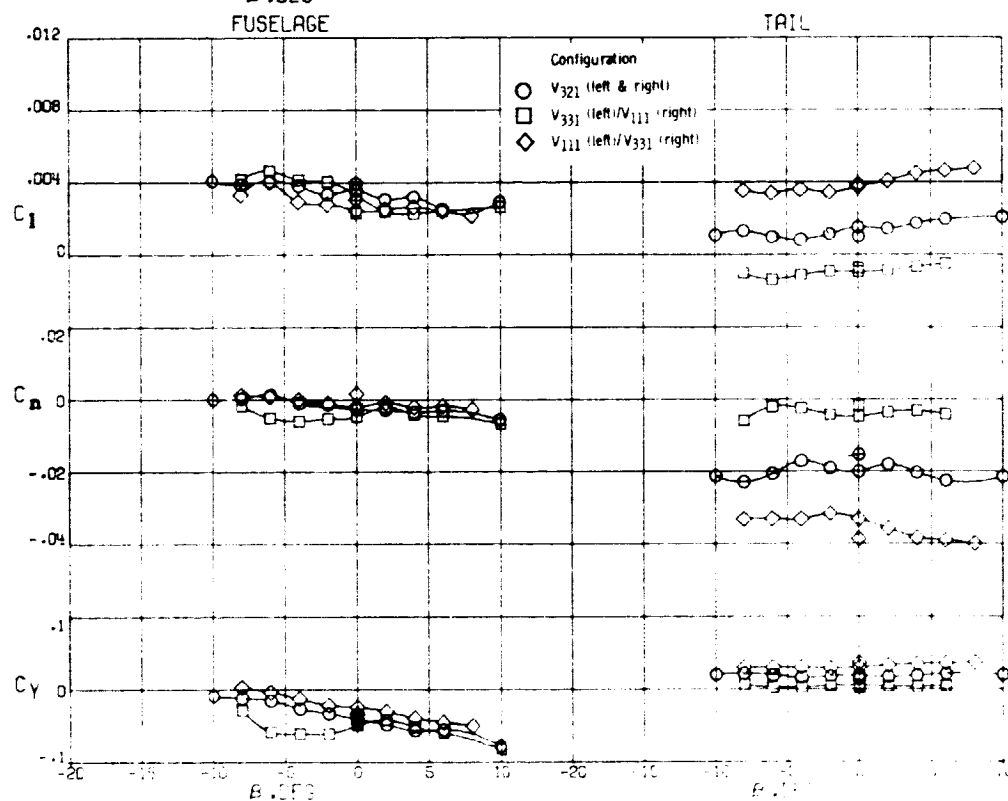


$\mu = 0.192$

Figure 19. - Concluded.



	α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
○	2.3	R	.056	4.7	-1.9	3.8	-2.1	1.1
□	3.8	R	.055	4.7	-1.9	3.8	-2.4	1.4
◇	3.7	R	.056	4.6	-1.9	3.7	-2.4	1.4



$\mu = 0.057$

Figure 20. Comparison of the lateral-directional characteristics of the baseline V-tail with two nonsymmetric dihedral configurations.

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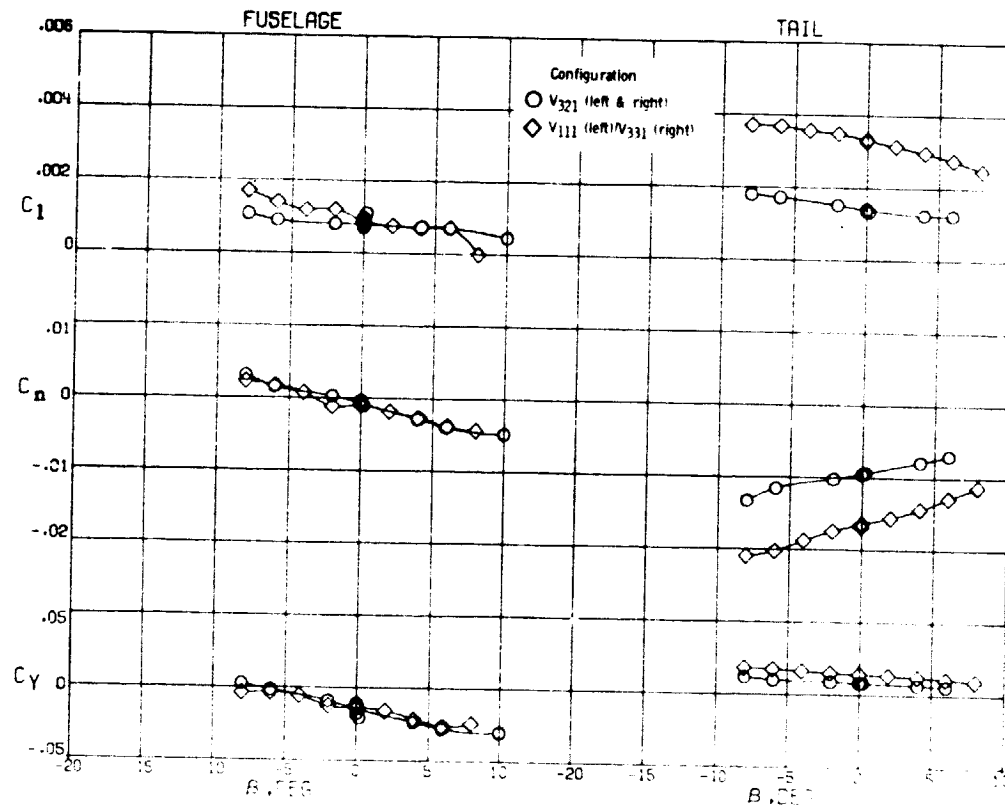
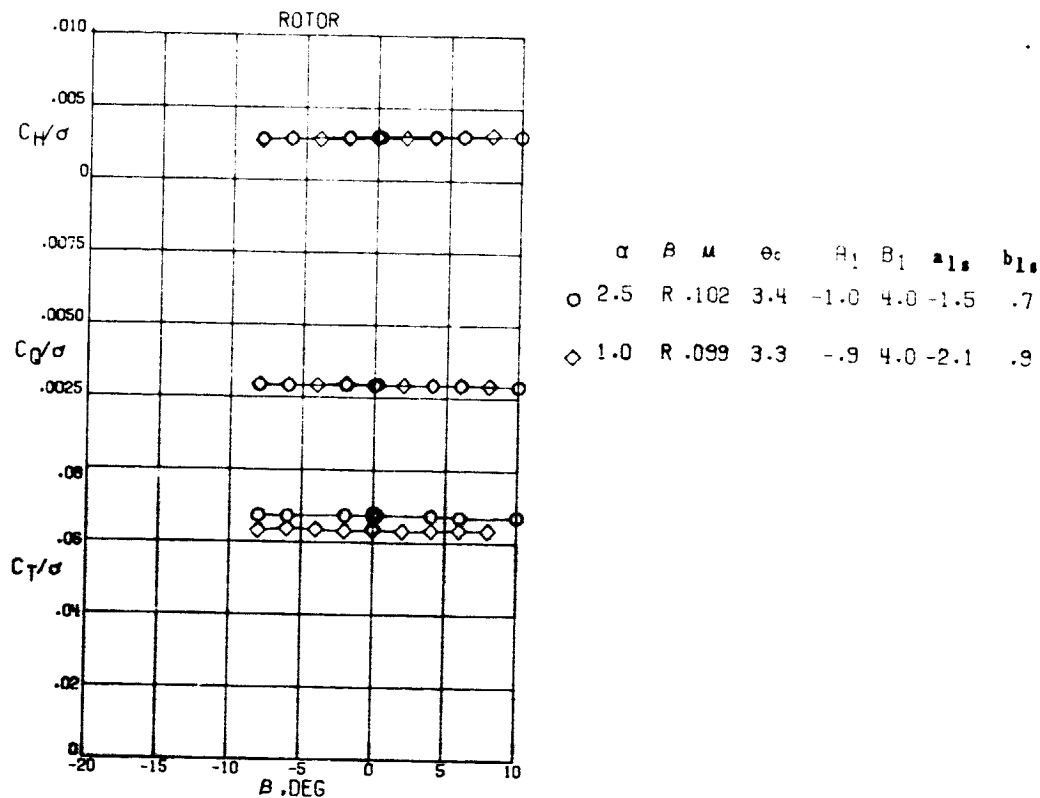


Figure 20. - Continued.

(b) $M = 0.102$

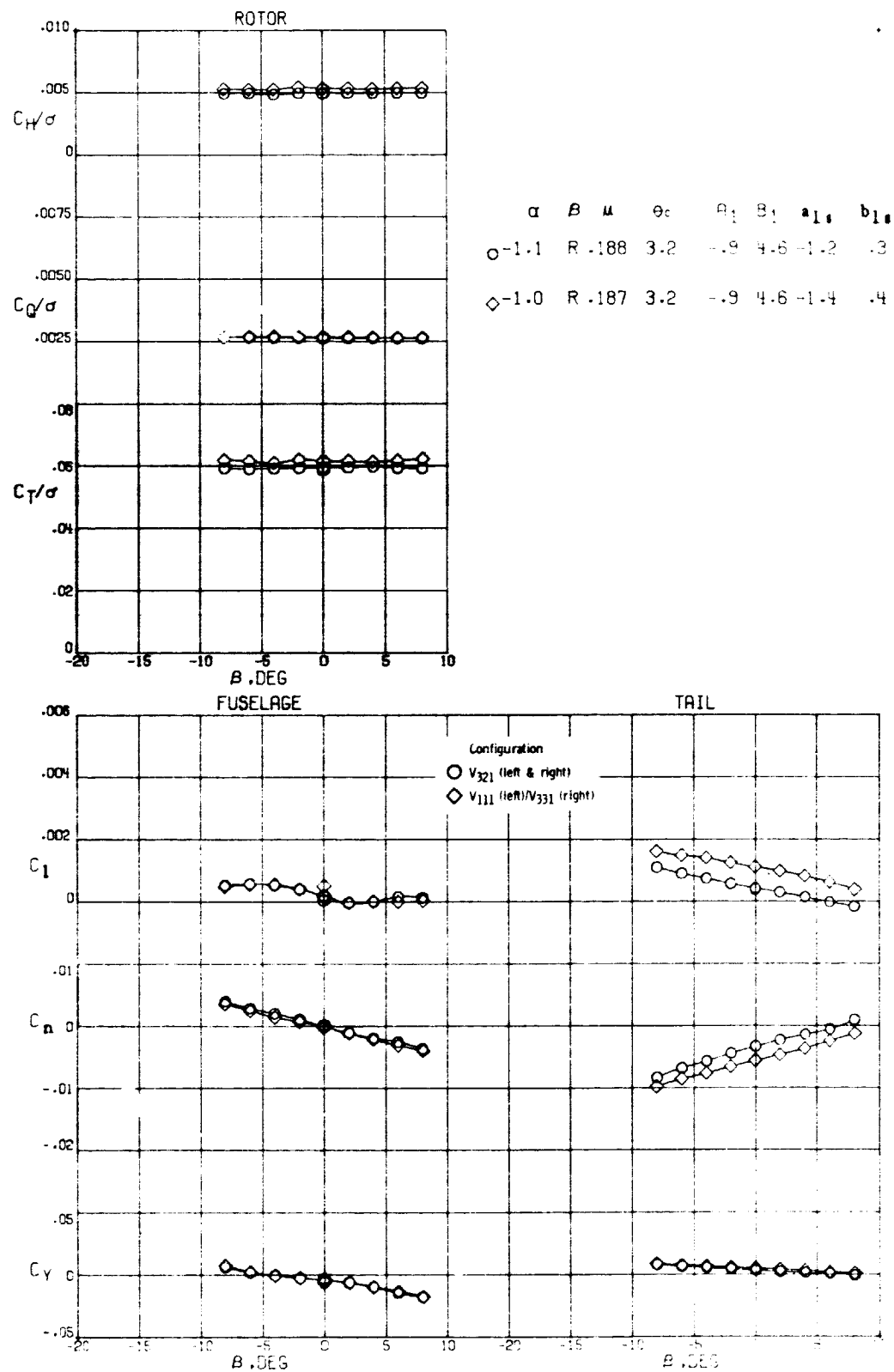
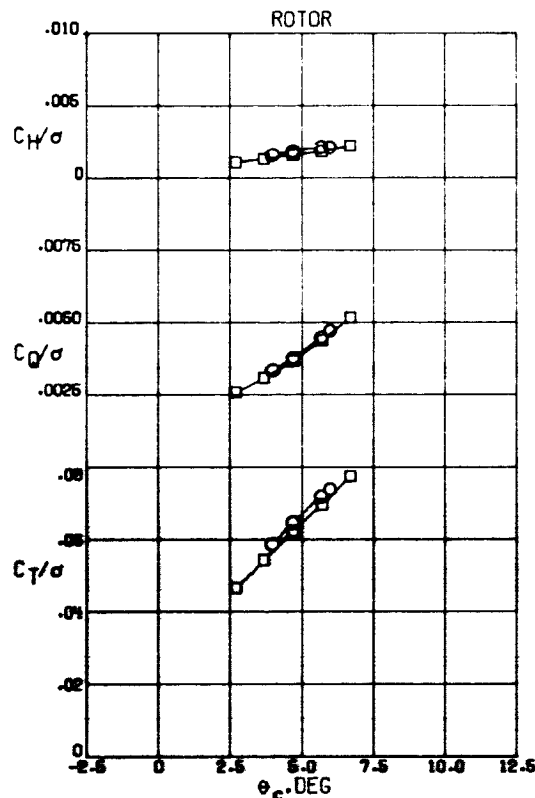


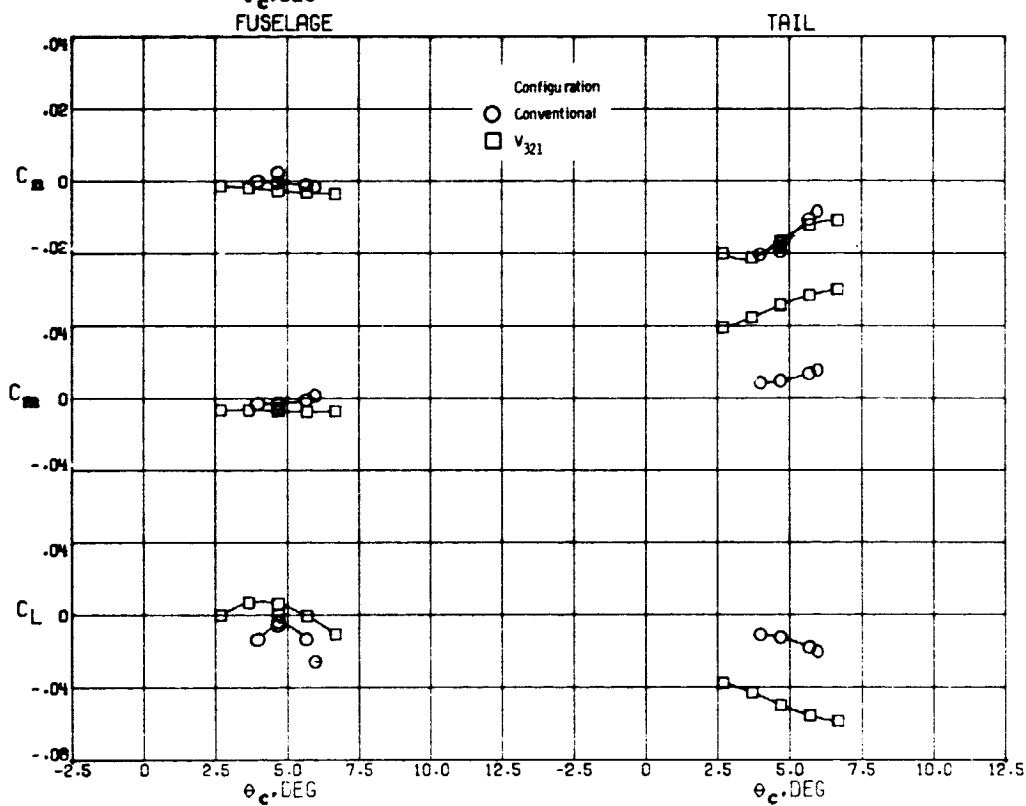
Figure 20.- Concluded.

(c) $\mu = 0.192$

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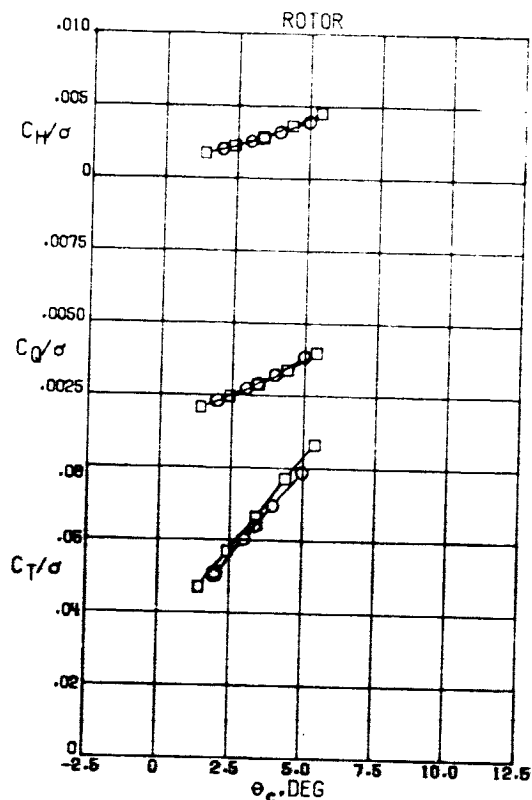


α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
3.7	-0.0	.057	R	-9	3.7	-2.3	1.4
2.3	.0	.056	R	-9	3.8	-2.2	1.1

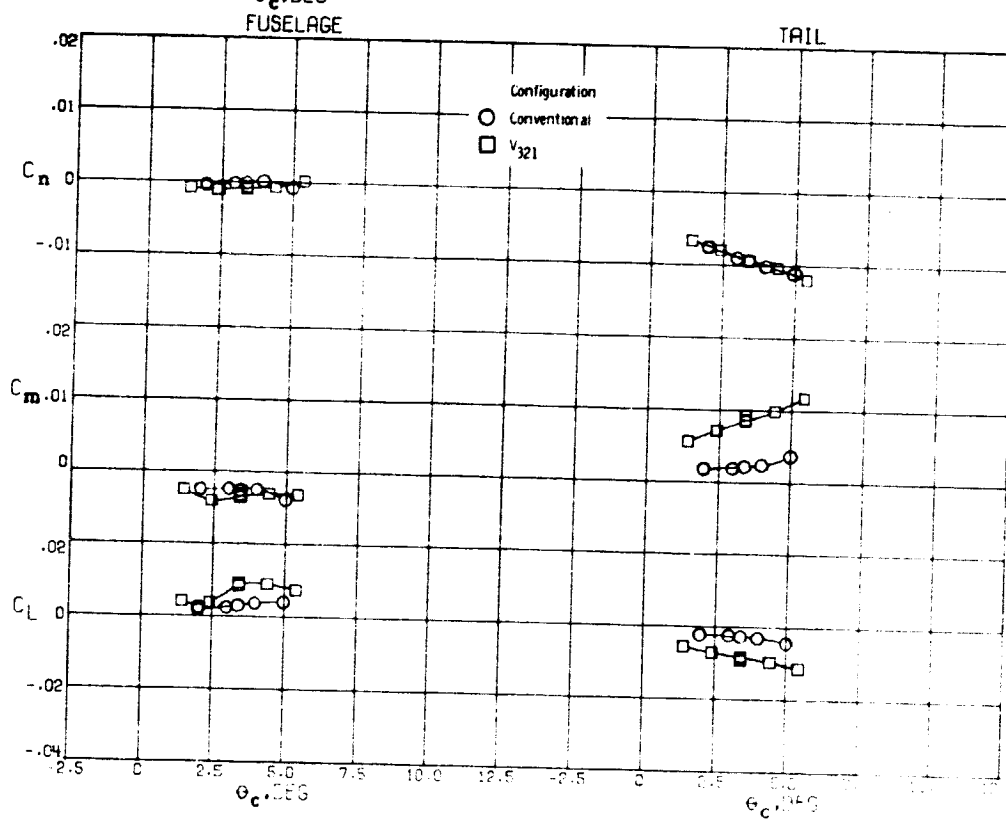


(a) $\mu = 0.057$

Figure 2L - Comparison of rotor collective effects on the conventional tail and the baseline V-tail.



α	β	μ	θ_c	B_1	B_2	a_{1s}	b_{1s}
1.0	.0	.100	R	-1.9	4.0	-2.0	.7
2.5	.0	.102	R	-1.0	4.0	-1.4	.6



b: $\mu = 0.102$

Figure 21. - Continued.

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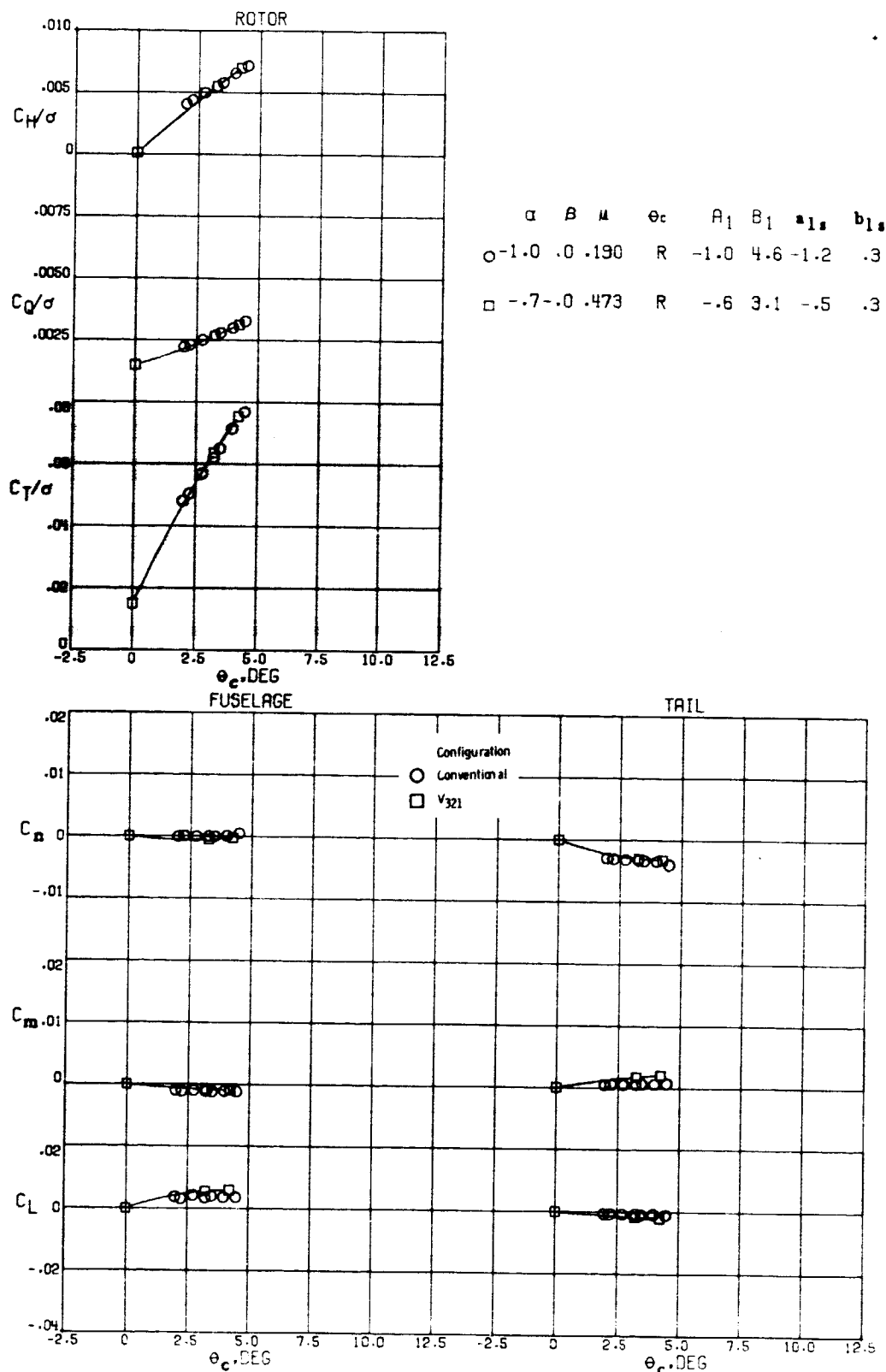
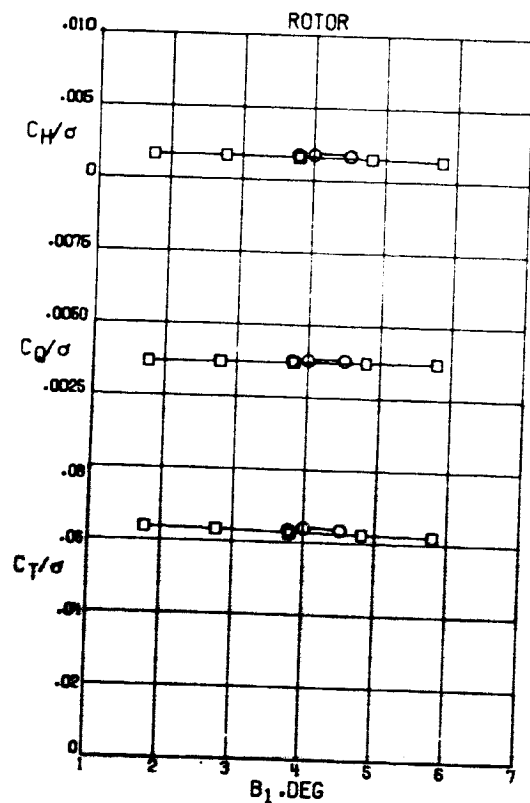
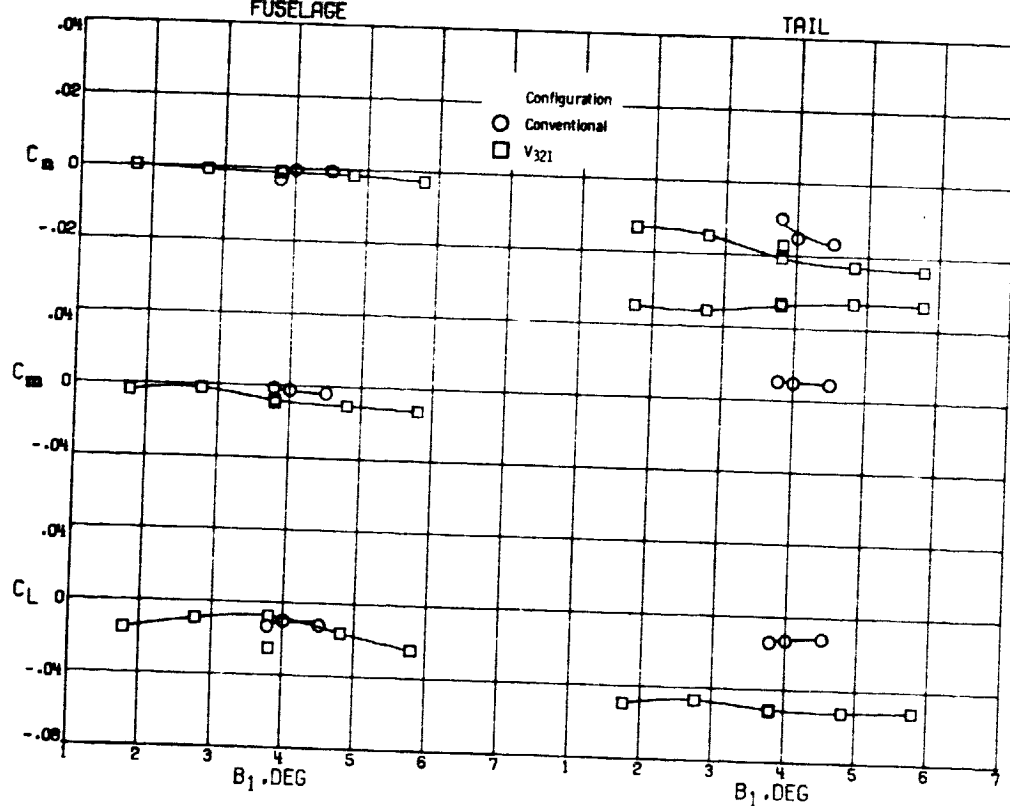


Figure 21- Concluded.



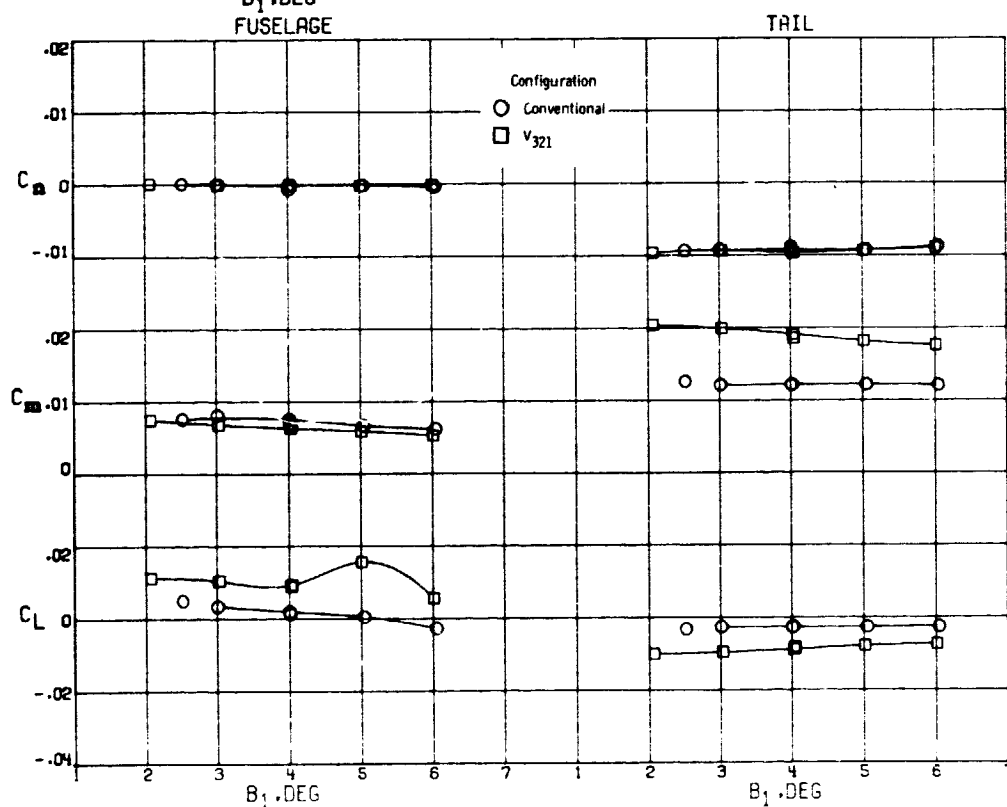
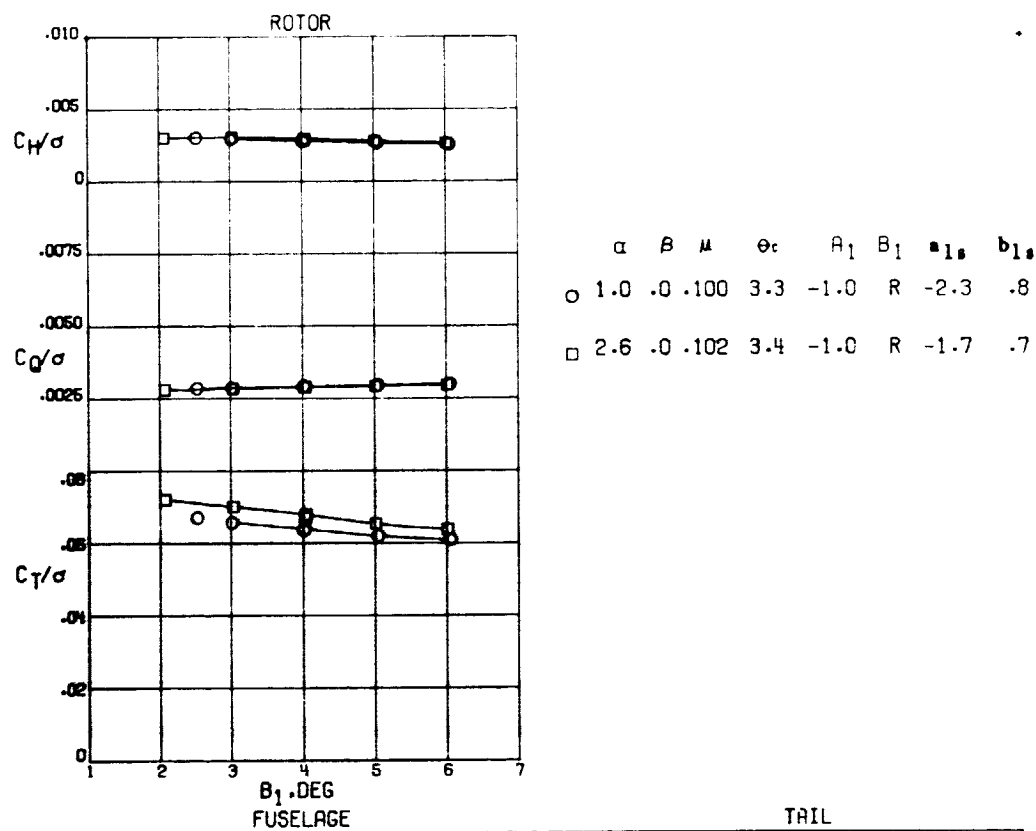
α	β	μ	θ_c	A_1	B_1	a_{1s}	b_{1s}
3.7	-0.0	.056	4.6	-.9	R	-2.5	1.5
2.3	-0.0	.056	4.7	-1.0	R	-2.3	1.1



(a) $\mu = 0.057$

Figure 22. - Comparison of rotor longitudinal cyclic effects on the conventional tail and the baseline V-tail.

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for $\mu = 0.102$

Figure 22.- Continued.

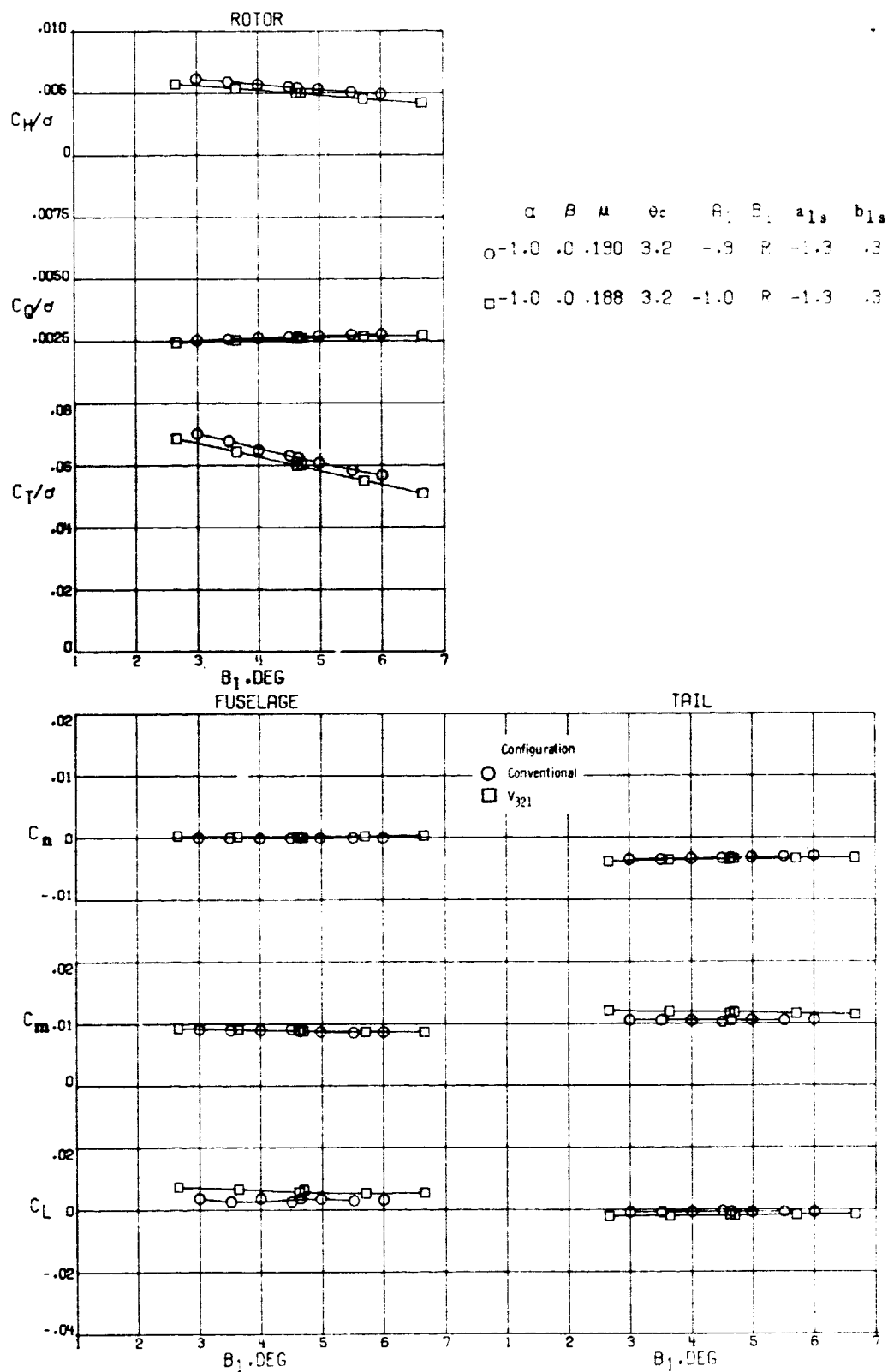


Figure 22.- Concluded.

$M = 0.192$

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